

Chapter 12

Phosphoric Acid Production

The phosphoric acid production industry consists of 21 facilities that were active as of September 1989,¹ employed the wet phosphoric acid production process, and generated two special wastes from mineral processing: process wastewater and phosphogypsum. The data included in this chapter are discussed in additional detail in a technical background document in the supporting public docket for this report.

12.1 Industry Overview

There are two processes for producing phosphoric acid: (1) the wet process, which is a mineral processing operation and is studied here, and (2) the furnace process. Furnace process phosphoric acid production uses elemental phosphorus rather than beneficiated phosphate rock as a feedstock and, therefore, wastes generated by the process are not mineral processing special wastes according to the Agency's definition of mineral processing. Consequently, furnace process production of phosphoric acid is not within the scope of this report.

About 95 percent of the commercial phosphoric acid produced by the wet process is used in the production of fertilizers and animal feed, with a small portion used as a feedstock in chemical processing operations.² Typically, the fertilizer and feed plants are co-located with the phosphoric acid facilities.

As shown in Exhibit 12-1, the majority of the 21 active wet process facilities are located in the southeast, with 12 in Florida, three in Louisiana, and one in North Carolina. Production data and dates of initial operation and modernization were provided by all 21 facilities, although two claimed confidential status for their information. The dates of initial operation for the 19 non-confidential facilities ranges from 1945 to 1986.³ Most of these facilities have undergone modernization within the last ten years, although six facilities have not been upgraded in over 20 years. The 19 reporting non-confidential facilities have a combined annual production capacity of over 11 million metric tons and a 1988 aggregate production of nearly 8.5 million metric tons; the 1988 capacity utilization rate, therefore, was approximately 77 percent. Several facilities, however, operated at low utilization rates (i.e. three facilities reported rates of 15.8, 30.1 and 37.5 percent).

The fertilizer industry, the largest user of phosphoric acid, suffered poor financial conditions for much of the 1980s. These conditions were the result of low domestic demand and reduced foreign buying. Domestic demand for phosphoric acid was boosted by the 1988 recovery of the farm economy and was expected to continue to grow as crop prices and planted acreage increased in 1989. Non-fertilizer uses of phosphoric acid declined during the 1980s due to strict regulations governing the use of phosphates in household products and a decline in industrial demand.⁴

The wet process consists of three operations: digestion, filtration, and concentration, as shown in Exhibit 12-2.⁵ Beneficiated phosphate rock is dissolved in phosphoric acid; sulfuric acid is added to this solution and chemically digests the calcium phosphate. The product of this operation is a slurry that consists

¹ At least two facilities were on standby in 1988, Agrico's Ft. Madison, Iowa and Hahnville (Taft), Louisiana facilities; they are not included in this analysis.

² Bureau of Mines, 1987. Minerals Yearbook, 1987 Ed., p. 676.

³ Phosphoric acid producers, 1989. Company Responses to the "National Survey of Solid Wastes from Mineral Processing Facilities," U.S.EPA, 1989.

⁴ Standard & Poor's, "Chemicals: Basic Analysis," Industry Surveys, October 13, 1988 (Section 3), p. C20.

⁵ Environmental Protection Agency, 1986. Evaluation of Waste Management for Phosphate Processing. Prepared by PEI Associates for U.S. EPA, Office of Research and Development, Cincinnati, OH, August, 1986.

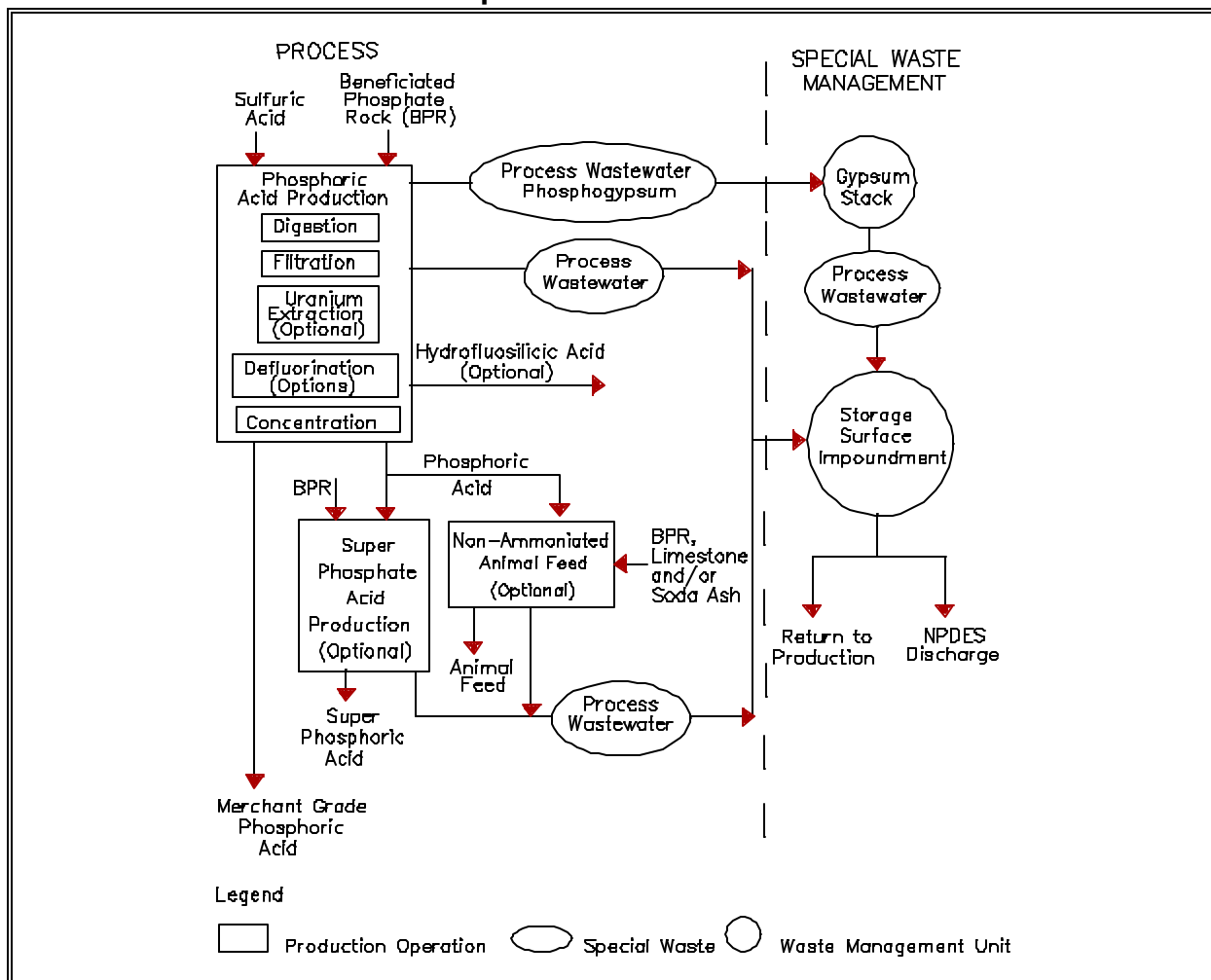
Exhibit 12-1 Wet Processing Phosphoric Acid Plants

Operator	Location	Parent Company
Agrico	Donaldsonville, LA	Freeport-McMoRan Res. Part.
Agrico	Mulberry (Pierce), FL	Freeport-McMoRan Res. Part.
Agrico	Uncle Sam, LA	Freeport-McMoRan Res. Part.
Arcadian	Geismar, LA	(same as operator)
Central Phos.	Plant City, FL	CF Industries
CF Chemicals	Bartow (Bonnie), FL	(same as operator)
Chevron Chem.	Rock Springs, WY	Chevron Corp.
Conserv	Nichols, FL	(same as operator)
Farmland Ind.	Bartow (Pierce), FL	(same as operator)
Fort Meade Chem.	Fort Meade, FL	US Agri-Chem and WR Grace
Gardinier	Riverview (Tampa), FL	(same as operator)
IMC Fertilizer	New Wales (Mulberry), FL	(same as operator)
Mobil Mining	Pasadena, TX	Mobil Oil Corp.(Mobil Corp.)
Nu-South Ind.	Pascagoula, MS	Nu-West Industries
Nu-West	Soda Springs (Conda), ID	(same as operator)
Occidental Chem.	White Springs, FL	Occidental Petroleum
Royster	Mulberry, FL	Cedar Holding Co.
Royster	Palmetto (Piney Pt), FL	Cedar Holding Co.
Seminole Fert.	Bartow, FL	(same as operator)
JR Simplot	Pocatello, ID	(same as operator)
Texasgulf	Aurora, NC	(same as operator)

of the phosphoric acid solution and a suspended solid, calcium sulfate, commonly known as phosphogypsum. The slurry is routed to a filtration operation where the suspended phosphogypsum is separated from the acid solution. The acid isolated during filtration is concentrated through evaporation to produce "merchant-grade" (54 percent) phosphoric acid. The phosphogypsum is re-slurried, this time in recycled process wastewater, so that it can be pumped to the disposal area. In addition to the large volume of phosphogypsum generated by the wet process, large volumes of process wastewaters are produced, primarily from phosphogypsum transport, phosphoric acid concentration, and process temperature control and cooling. These wastewaters are managed in impoundments and primarily recycled, although some facilities have permits to discharge wastewaters to ground water or surface water.⁶

⁶ As discussed in detail in the preamble to the final rule that retained the exclusion from RCRA Subtitle C regulations for process wastewater (see 55 FR 2322, January 23, 1990), these are not the only sources of process wastewater. "Process wastewater from phosphoric acid production" also includes phosphogypsum stack runoff, process wastewater generated from the uranium recovery step of phosphoric acid production, process wastewater from animal feed production (including defluorination but excluding ammoniated animal feed production), and process wastewater from superphosphate production.

Exhibit 12-2
Phosphoric Acid Production



12.2 Waste Characteristics, Generation, and Current Management Practices

12.2.1 Phosphogypsum

Phosphogypsum, which has an average particle diameter of less than 0.02 millimeters, is primarily composed of calcium sulfate, silicon, phosphate, and fluoride. It also typically contains a variety of radionuclides, including uranium-230, uranium-234, thorium-230, radium-226, radon-222, lead-210 and polonium-210.

Using available data on the composition of phosphogypsum, EPA evaluated whether leachate from this material exhibits any of the four characteristics of hazardous waste: corrosivity, reactivity, ignitability, and extraction procedure (EP) toxicity. Based on available information and professional judgment, the Agency does not believe phosphogypsum is reactive, corrosive, or ignitable. Some phosphogypsum samples, however, exhibit the characteristic of EP toxicity. EP leach test concentrations of all eight inorganic constituents with EP toxicity regulatory levels are available for 28 phosphogypsum samples from 11 facilities of interest. Of these constituents, only chromium concentrations exceed the EP toxicity levels; this occurred in 2 of 28 samples analyzed, by as much as a factor of 9. Both samples that failed the EP toxicity criterion for chromium were from the Rock Springs facility. The phosphogypsum samples that failed the EP

toxic level were also analyzed using the SPLP leach test, and for both samples, concentrations of chromium measured by the SPLP leach test were well below the EP toxicity regulatory levels.

Non-confidential waste generation rate data were reported for phosphogypsum by 18 of the 21 processing facilities and estimated for the remaining three. The aggregate annual industry-wide generation of phosphogypsum was approximately 47.6 million metric tons in 1988, yielding a facility average of about 2.26 million metric tons per year. Reported facility generation rates ranged from .14 to 6.8 million metric tons of phosphogypsum. The sector-wide ratio of phosphogypsum to phosphoric acid ranges from 3.7 to 5.6, averaging 4.9 for the sector.

Phosphogypsum is managed in basically the same way at virtually all of the 21 active facilities. The phosphogypsum removed by the filtration step in the phosphoric acid production process is slurried in process wastewater and pumped to one or more impoundments located on the top of an on-site waste pile known in the industry as a gypsum stack. In the impoundment, the gypsum solids are allowed to settle; the liquid (process wastewater) is either directly removed from the settling pond and sent to a nearby cooling pond or indirectly removed after it seeps through the stack and is collected by ditches or ponds that circumscribe the stack.

Periodically, the phosphogypsum slurry is diverted from one impoundment on the gypsum stack to another and the first impoundment is allowed to dry. The dewatered phosphogypsum is excavated from the inactive pond and used to build up the dike that forms the impoundment and then the impoundment is returned to active service. In this manner, the stack with its series of settling ponds increases in height and accumulates additional phosphogypsum. The ultimate height and area of the resulting stack depends on the configuration of the facility's property and the ability of the native soils to support the load of the stack. After a stack is "full", rainwater that runs off or leaches through the stack continues to be collected in the perimeter ditch and is usually managed with water collected from active stacks.

The average dimensions of the gypsum stacks are 130 hectares (320 acres) at the base and 35 meters (115 feet) in height; on a facility-specific basis the stacks range from about 20 to 260 hectares and 3 to 130 meters in height. The average dimensions of the settling ponds atop these stacks are 54 hectares and 1.4 meters in depth; on a facility-specific basis the ponds range in size from 2.6 to 26 hectares and in depth from .3 to 7.6 meters.

12.2.2 Process Wastewater

Process wastewaters are generated at several points in phosphoric acid production, including phosphoric acid concentration, and phosphoric acid temperature control and cooling. These wastewaters contain significant quantities of chloride, fluoride, phosphate, and have a pH that ranges from 0.5 to 7.8.

Using available data on the composition of phosphoric acid process wastewater, EPA evaluated whether the wastewater exhibits any of the four characteristics of hazardous waste: corrosivity, reactivity, ignitability, and extraction procedure (EP) toxicity. Based on available information and professional judgment, the Agency does not believe the wastewater is reactive or ignitable. Some wastewater samples, however, exhibit the characteristics of corrosivity and EP toxicity. Measurements of pH in 42 out of 68 process wastewater samples from a total of 14 facilities indicated that the wastewater was corrosive, sometimes with pH values as low as 0.5 (the lower bound pH limit for the purpose of defining corrosive waste is 2.0). EP leach test concentrations of all eight constituents with EP toxicity regulatory levels are available for process wastewaters from 7 facilities. Of these constituents, cadmium and chromium concentrations were found to sometimes exceed the EP toxicity levels, and one sample was found to have a selenium concentration equal to the EP toxicity regulatory level. Concentrations of cadmium exceeded the EP toxic level in process wastewater samples from three facilities, Pocatello, Geismar, and Aurora. Cadmium was present at concentrations in excess of the EP toxic level in 19 out of 30 samples by as much as a factor of 8. From a total of 30 samples, chromium concentrations exceeded the EP toxicity regulatory level (by as much as a factor of 2.7) in only 3 samples (2 of which were from the Pocatello facility and 1 from the Pascagoula facility). SPLP leach test results for phosphoric acid process wastewater samples were well below the EP toxicity regulatory levels for all constituents.

Non-confidential waste generation rate data were fully reported for process water by 12 of the 21 processing facilities and estimated for the remaining nine. The aggregate annual industry-wide generation of process water was approximately 1.77 billion metric tons (468 billion gallons) in 1988, yielding a facility average of 84 million metric tons per year (60 million gallons per day [mgd]). Reported facility annual generation rates ranged from 13 to 280 million metric tons

of process wastewater (9.3 to 200 mgd). The ratio of process water managed to phosphoric acid produced ranges from 102 to 494.

The process wastewater from the stacks, along with non-transport process waters, are typically managed in on-site impoundments, commonly known as cooling ponds. These impoundments are used in conjunction with the gypsum stacks in an integrated system. Water from these ponds is reused in on-site mineral processing and other activities. The facility operators ideally seek to maintain a water balance such that no treatment and discharge of process wastewater to surface water is necessary, although some facilities are equipped to treat and discharge some wastewater during periods of high precipitation.

The average dimensions of the cooling ponds are nearly 60 hectares (145 acres) of surface area and 2.6 meters (8.5 feet) of depth; on a facility-specific basis the surface area ranges from 1 to 260 hectares (2.5 to 640 acres) and depth ranges from 0.3 to 6.7 meters (1 to 21 feet).

12.3 Potential and Documented Danger to Human Health and The Environment

This section addresses two of the study factors required by §8002(p) of RCRA: (1) potential danger (i.e., risk) to human health and the environment; and (2) documented cases in which danger to human health or the environment has been proven. The Agency's evaluation of the potential dangers posed by phosphogypsum and phosphoric acid process wastewater uses the evidence presented in numerous documented cases of danger to human health and the environment to establish that these wastes can threaten human health and the environment as they are currently managed. Overall conclusions about the hazards associated with phosphogypsum and phosphoric acid process wastewater are provided after these two study factors are discussed.

12.3.1 Risks Associated With Phosphogypsum and Phosphoric Acid Process Wastewater

Any potential danger to human health and the environment from phosphogypsum and phosphoric acid process wastewater depends on the presence of toxic and radioactive constituents in the wastes that may present a hazard and the potential for exposure to these constituents. The Agency has documented cases of dangers posed by these wastes via ground and surface water pathways (see Section 12.3.2), and has previously evaluated potential air pathway dangers from the management of phosphogypsum in stacks. Based on the insights provided by analyses of the hazards posed by phosphogypsum and phosphoric acid wastewater, and information on waste characteristics and management developed for this study, the Agency evaluated the intrinsic hazard of these wastes and the potential for toxic and radioactive constituents from these wastes to pose threats to human health and the environment. This evaluation discusses constituents of potential concern in the wastes and assesses the management practice and environmental setting characteristics that affect the potential for these wastes to pose risks through the ground-water, surface water, and air pathways.

Phosphogypsum Constituents of Potential Concern

EPA identified chemical constituents in phosphogypsum that may present a hazard by collecting data on the composition of this waste and evaluating the intrinsic hazard of the chemical constituents.

Data on Phosphogypsum

EPA's characterization of phosphogypsum and its leachate is based on data from three sources: (1) a 1989 sampling and analysis effort by EPA's Office of Solid Waste (OSW); (2) industry responses to a RCRA §3007 request; and (3) sampling and analysis conducted by EPA's Office of Research and Development (ORD) in 1986. These data provide information on the concentrations of 21 metals, radium-226, thorium-232, uranium-238, gross alpha and beta radiation, a number of other inorganic constituents (i.e., phosphate, phosphorus, fluoride, chloride, sulfate, ammonia,

and nitrate), and five organic constituents in total and leach test analyses. Thirteen of the 21 phosphoric acid production facilities are represented by these data.

Concentrations of most (i.e., 21 of 38) constituents in solid samples of phosphogypsum vary considerably among the samples analyzed (i.e., the range of values spans more than three orders of magnitude). Concentration data provided by industry represent a larger number of samples and span a wider range of values than do data from EPA's sampling and analysis efforts. EPA sampling and analysis data for some constituents (i.e., arsenic, selenium, silver, and thallium) do not contribute to the characterization of phosphogypsum because the detection limits used in analyzing these samples are higher than any detected concentrations from analyses of other samples.

Concentrations of most constituents in leach test analyses of phosphogypsum vary considerably less than do concentrations in solid samples (i.e., the ranges of values span less than two orders of magnitude). However, concentrations of chromium, copper, iron, lead, and zinc in EP leach test analyses vary over three or more orders of magnitude. Concentrations from analyses using the EP leach test method are consistently higher than from SPLP method analyses.

Process for Identifying Constituents of Potential Concern

As discussed in Chapter 2, the Agency evaluated the waste composition data summarized above to determine if phosphogypsum contains any chemical constituents that could pose an intrinsic hazard. The Agency performed this evaluation by first comparing the concentration of chemical constituents to screening criteria that reflect the potential for hazards, and then by evaluating the environmental persistence and mobility of constituents that are present at levels above the criteria. These screening criteria were developed using assumed scenarios that are likely to overestimate the extent to which constituents in phosphogypsum are released to the environment and migrate to possible exposure points. As a result, this process eliminates from further consideration only those constituents that clearly do not pose a risk.

The Agency used three categories of screening criteria that reflect the potential for hazards to human health, aquatic ecosystems, and air and surface/ground water resources (see Exhibit 2-3). Given the conservative (i.e., protective) nature of these screening criteria, contaminant concentrations in excess of the criteria should not, in isolation, be interpreted as proof of hazard. Instead, exceedances of the criteria indicate the need to evaluate the potential hazards of the waste in greater detail.

Identified Constituents of Potential Concern

Exhibits 12-3 and 12-4 present the results of the comparisons for phosphogypsum solid analyses and leach test analyses, respectively, to the screening criteria described above. These exhibits list all constituents for which at least one sample concentration exceeds a relevant screening criterion.

Of the 38 constituents analyzed in total analyses of phosphogypsum, only radium-226, uranium-238, chromium, and arsenic are present at concentrations exceeding the screening criteria (Exhibit 12-3). Maximum concentrations of these constituents are at most seven times the screening criteria. The sample concentrations of the first three of these constituents (i.e., all except arsenic) exceed screening criteria in at least half of the

Exhibit 12-3

Potential Constituents of Concern in Phosphogypsum Solids^(a)

Potential Constituents of Concern	No. of Times Constituent Detected/No. of Analyses for Constituent	Human Health Screening Criteria ^(b)	No. of Analyses Exceeding Criteria/No. of Analyses for Constituent	No. of Facilities Exceeding Criteria/No. of Facilities Analyzed for Constituent
Radium-226	29 / 29	Radiation ^(c)	26 / 29	6 / 7
Uranium-238	18 / 18	Radiation ^(c)	1 / 18	1 / 3
Chromium	34 / 43	Inhalation [*]	8 / 43	4 / 8
Arsenic	35 / 43	Ingestion [*] Inhalation [*]	34 / 43 29 / 43	2 / 8 1 / 8

- (a) Constituents listed in this table are present in at least one sample from at least one facility at a concentration that exceeds a relevant screening criterion. The conservative screening criteria used in this analysis are listed in Exhibit 2-3. Constituents that were not detected in a given sample were assumed not to be present in the sample.
- (b) Human health screening criteria are based on exposure via incidental ingestion and inhalation. Human health effects include cancer risk and noncancer health effects. Screening criteria noted with "*" are based on a 1×10^{-5} lifetime cancer risk; others are based on noncancer effects.
- (c) Includes direct radiation from contaminated land and inhalation of radon decay products.

facilities analyzed. None of these constituents, however, exceed the screening criteria by more than a factor of 10.

- Radium-226, and uranium-238 concentrations exceed health-based screening criteria based on multiple radiation pathways. Exceedance of these criteria indicates that phosphogypsum could pose an unacceptable radiation risk if used in an unrestricted manner (for instance, direct radiation doses and doses from the inhalation of radon could be unacceptably high if phosphogypsum is used around homes).
- Chromium and arsenic concentrations exceed the health-based screening criteria for inhalation. This indicates that these constituents could pose a significant cancer risk (i.e., greater than 1×10^{-5}) if phosphogypsum were released to the ambient air as particles.
- Arsenic concentrations exceed the health-based screening criteria for incidental ingestion. This indicates that arsenic may pose a significant incremental lifetime health risk (i.e., greater than 1×10^{-5}) if a small quantity of phosphogypsum or soil contaminated with phosphogypsum is inadvertently ingested on a routine basis (e.g., airborne waste particles may be deposited on crops, or small children playing on abandoned stacks could inadvertently ingest the waste).

EPA sampling and analysis also indicates that levels of gross alpha and beta radiation from phosphogypsum are very high (10 to 100 pCi/g) relative to levels associated with typical soils (approximately 1 pCi/g).

Based on a comparison of leach test concentrations of 29 constituents to surface and ground-water pathways screening criteria (see Exhibit 12-4), 17 constituents were found to be of potential concern for water-based release and exposure. Among these 17 constituents, phosphorus, arsenic, lead, phosphate, manganese, molybdenum, and nickel exceed screening criteria in at least one-half of all facilities analyzed. Twelve constituents exceed the screening criteria by more than a factor of 10, but only chromium was measured in concentrations that exceed the EP toxicity regulatory level. All of these constituents are very persistent in the environment.

Exhibit 12-4
Potential Constituents of Concern in Phosphogypsum Leachate^(a)

Potential Constituents of Concern	No. of Times Constituent Detected/No. of Analyses for Constituent	Screening Criteria ^(b)	No. of Analyses Exceeding Criteria/No. of Analyses for Constituent	No. of Facilities Exceeding Criteria/No. of Facilities Analyzed for Constituent
Phosphorus	17 / 17	Aquatic Ecological	17 / 17	9 / 9
Arsenic	19 / 28	Human Health*	19 / 28	10 / 11
Lead	14 / 28	Human Health Resource Damage Aquatic Ecological	4 / 28 12 / 28 2 / 28	3 / 11 7 / 11 2 / 11
Phosphate	19 / 19	Aquatic Ecological	19 / 19	9 / 9
Manganese	21 / 22	Resource Damage	9 / 22	6 / 11
Molybdenum	16 / 20	Resource Damage	10 / 22	6 / 10
Nickel	19 / 22	Resource Damage Aquatic Ecological	2 / 22 10 / 20	2 / 11 6 / 11
Iron	20 / 20	Resource Damage Aquatic Ecological	6 / 20 1 / 20	4 / 10 1 / 10
Cadmium	26 / 28	Human Health Resource Damage Aquatic Ecological	4 / 28 7 / 28 7 / 28	3 / 11 4 / 11 4 / 11
Chromium	27 / 28	Human Health Resource Damage Aquatic Ecological	2 / 28 5 / 28 4 / 28	1 / 11 3 / 11 2 / 11
Silver	14 / 26	Aquatic Ecological	6 / 26	3 / 10
Fluoride	17 / 17	Human Health	3 / 17	2 / 9
Zinc	21 / 22	Human Health Resource Damage Aquatic Ecological	1 / 22 1 / 22 2 / 22	1 / 11 1 / 11 2 / 11
Antimony	5 / 22	Human Health	3 / 22	2 / 11
Copper	18 / 22	Human Health Resource Damage Aquatic Ecological	1 / 22 1 / 22 4 / 22	1 / 11 1 / 11 2 / 11
Mercury	3 / 24	Aquatic Ecological	1 / 24	1 / 10
Thallium	1 / 20	Human Health	1 / 20	1 / 10

(a) Constituents listed in this table are present in at least one sample from at least one facility at a concentration that exceeds a relevant screening criterion. The conservative screening criteria used in this analysis are listed in Exhibit 2-3. Constituents that were not detected in a given sample were assumed not to be present in the sample. The constituent concentrations used for this analysis are based on EP leach test results.

(b) Human health screening criteria are based on cancer risk or noncancer health effects. "Human health" screening criteria noted with an "*" are based on 1×10^{-5} lifetime cancer risk; others are based on noncancer effects.

These exceedances of the screening criteria have the following implications:

- Concentrations of arsenic, lead, cadmium, chromium, fluoride, zinc, antimony, copper, and thallium in phosphogypsum leachate exceed screening criteria based on human health risks. This indicates that, if phosphogypsum leachate were diluted less than 10-fold during migration to a drinking water exposure point, long-term chronic ingestion could cause adverse health effects due to the presence of these constituents. The concentration of arsenic in diluted phosphogypsum leachate could pose a cancer risk of greater than 1×10^{-5} from long-term drinking water exposures.
- Concentrations of phosphorus, lead, phosphate, nickel, iron, cadmium, chromium, silver, zinc, copper, and mercury in phosphogypsum leachate exceed screening criteria for protection of aquatic life. This means that phosphogypsum leachate could present a threat to aquatic organisms if it migrates (with less than 100-fold dilution) to surface waters.
- Lead, manganese, molybdenum, nickel, iron, cadmium, chromium, zinc, and copper concentrations in phosphogypsum leachate exceed ground and surface water resource damage screening criteria. This indicates that, if released and diluted by a factor of 10 or less, leachate from this waste may contain these constituents in concentrations sufficient to severely restrict the potential future uses of nearby ground and surface water resources.

These exceedances of the screening criteria, by themselves, do not demonstrate that phosphogypsum poses a significant risk, but rather indicate that it may present a hazard. To determine the potential for phosphogypsum to cause significant impacts, EPA proceeded to analyze the actual conditions that exist at the facilities that generate and manage the waste (see the following section on release, transport, and exposure potential).

Process Wastewater Constituents of Potential Concern

Using the same process summarized above for phosphogypsum, EPA identified chemical constituents in phosphoric acid process wastewater that could conceivably pose a risk by collecting data on the composition of this waste, and evaluating the intrinsic hazard of the chemical constituents present in the process wastewater.

Data on Process Wastewater Composition

EPA's characterization of process wastewater and its leachate is based on data from: (1) a 1989 sampling and analysis effort by EPA's Office of Solid Waste (OSW), and (2) industry responses to a RCRA §3007 request. These data provide information on the concentrations of 21 metals, radium-226, uranium-238, gross alpha and gross beta radiation, a number of other inorganic species (i.e., chloride, fluoride, phosphate, nitrate, sulfate, and ammonia), and seven organic compounds in total and leach test analyses. Data on the pH of process wastewater was also collected: at most facilities, the pH is between 1 and 2 standard units, however, two facilities report minimum levels below 1, and 1 facility reports levels between 6.5 and 8 standard units. The waste composition data represent samples collected from 17 of the 21 active phosphoric acid production facilities. As with the concentration data for phosphogypsum, data on the concentrations of most constituents in process wastewater vary over two or three orders of magnitude. Concentrations from leach test analyses of the wastewater vary to a smaller extent.

Concentrations of most (i.e., 22 of 40) constituents in total analyses of process wastewater vary considerably among the samples analyzed (i.e., the range of values spans more than three orders of magnitude). Concentration data provided by industry represent a larger number of samples and span a wider range of values than do data from EPA's sampling and analysis efforts. Concentrations of most constituents in leach test analyses of process wastewater vary considerably less than do concentrations in total analyses (i.e., the ranges of values span two or three orders of magnitude for only five constituents). Because the waste characterization provided by total analyses and leach test analyses are similar, and because the quantity of data is much greater for total analyses, the following analysis of potential constituents of concern in process wastewater is based on the results of total analyses only.

Identified Constituents of Potential Concern

Exhibit 12-5 presents the results of the comparisons for the phosphoric acid process wastewater total analyses to the screening criteria described above. This exhibit lists all constituents for which at least one sample concentration exceeds a relevant screening criterion.

Of the 40 constituents analyzed in process wastewater (and its leachate), levels of arsenic, phosphorus, phosphate, cadmium, chromium, aluminum, gross alpha and beta radiation, radium-226, phenol, iron, manganese, nickel, lead, vanadium, sulfate, copper, boron, molybdenum, antimony, thallium, silver, cobalt, mercury, fluoride, zinc, chloride, beryllium, selenium, and pH exceed the Agency's screening criteria. All of these constituents are metals or other inorganics that do not degrade in the environment.

The first 22 of these 30 constituents are of relatively greater potential concern because their concentrations in samples from at least one-half of all facilities analyzed exceed screening criteria (based on separate evaluations of total liquid and leach test results). Maximum concentrations of phosphorus, phosphate, arsenic, and phenol exceed screening criteria by factors of greater than 1,000 and concentrations of 15 other constituents exceed screening criteria by factors of at least 10. As discussed in Section 12.2, cadmium, chromium, and selenium concentrations are occasionally greater than or equal to the EP toxicity regulatory levels, and the pH is frequently below 2.0, the lower-bound limit for defining a corrosive waste.

These exceedances of the screening criteria indicate the potential for the following types of impacts under the following conditions:

- Concentrations of arsenic, cadmium, chromium, radium-226, lead, vanadium, copper, antimony, thallium, fluoride, and selenium in process wastewater exceed screening criteria based on human health risks. This indicates that, if process wastewater was diluted 10-fold during migration to a drinking water exposure point, long-term exposures could cause adverse health effects due to the presence of these constituents. Based on long-term drinking water exposures, arsenic concentrations could pose a significant cancer threat (i.e., a lifetime risk of greater than 1×10^{-5}).
- Concentrations of arsenic, cadmium, chromium, aluminum, gross alpha and beta radiation, radium-226, phenol, iron, manganese, nickel, lead, vanadium, sulfate, copper, boron, molybdenum, cobalt, silver, fluoride, chloride, beryllium, and selenium in process wastewater exceed ground and surface water resource damage screening criteria. This indicates that, if released and diluted less than 10-fold in ground water or less than 100-fold in surface water, phosphoric acid process wastewater may contain these constituents in concentrations sufficient to severely restrict the uses of nearby ground- and surface water resources. In addition, the pH of phosphoric acid plant process wastewater is very low, and water resources may be damaged by the highly acidic nature of this waste.
- Concentrations of arsenic, phosphorus, phosphate, cadmium, chromium, aluminum, iron, nickel, lead, copper, silver, mercury, zinc, and selenium in process wastewater exceed screening criteria based on aquatic life protection. The low pH of the wastewater is also well below the levels that most aquatic life can tolerate. This means that phosphoric acid plant process wastewater may present a threat to aquatic organisms if it migrates (with 100-fold dilution) to surface waters.

These exceedances, by themselves, do not prove that the wastewater poses a significant risk, but rather indicate that it may present a hazard under a very conservative, hypothetical set of release, transport, and exposure conditions. To determine the potential for this waste to cause significant impacts, EPA proceeded to the next step of the risk assessment to analyze the actual conditions that exist at the facilities that generate and manage the wastewater.

Exhibit 12-5
Potential Constituents of Concern in Phosphoric Acid Process Wastewater
(Total)^(a)

Potential Constituents of Concern	No. of Times Constituent Detected/No. of Analyses for Constituent	Screening Criteria ^(b)	No. of Analyses Exceeding Criteria/ No. of Analyses for Constituent	No. of Facilities Exceeding Criteria/ No. of Facilities Analyzed for Constituent
Arsenic	77 / 78	Human Health* Resource Damage Aquatic Ecological	76 / 78 37 / 78 21 / 78	15 / 15 8 / 15 5 / 15
Phosphorus	31 / 31	Aquatic Ecological	31 / 31	10 / 10
Phosphate	38 / 38	Aquatic Ecological	38 / 38	9 / 9
Cadmium	73 / 77	Human Health Resource Damage Aquatic Ecological	65 / 77 69 / 77 68 / 77	14 / 15 14 / 15 14 / 15
Chromium	75 / 78	Human Health Resource Damage Aquatic Ecological	26 / 78 65 / 78 44 / 78	8 / 15 14 / 15 9 / 15
Aluminum	58 / 59	Resource Damage Aquatic Ecological	42 / 59 53 / 59	8 / 10 10 / 10
Gross Alpha	46 / 47	Resource Damage	40 / 47	11 / 11
Gross Beta	34 / 47	Resource Damage	30 / 47	9 / 9
Radium-226	86 / 89	Human Health* Resource Damage	26 / 89 14 / 89	9 / 13 5 / 13
Phenol	4 / 5	Resource Damage	4 / 5	3 / 3
Iron	54 / 55	Resource Damage Aquatic Ecological	52 / 55 33 / 55	10 / 10 6 / 10
Manganese	44 / 44	Resource Damage	41 / 44	10 / 10
Nickel	68 / 72	Resource Damage Aquatic Ecological	14 / 72 57 / 72	8 / 14 12 / 14
Lead	64 / 75	Human Health Resource Damage Aquatic Ecological	28 / 75 51 / 75 22 / 75	8 / 15 12 / 15 7 / 15
Vanadium	38 / 41	Human Health Resource Damage	18 / 41 30 / 41	5 / 10 9 / 10
Sulfate	57 / 57	Resource Damage	43 / 57	10 / 11
Copper	69 / 74	Human Health Resource Damage Aquatic Ecological	1 / 74 1 / 74 37 / 74	1 / 14 1 / 14 7 / 14

(a) Constituents listed in this table are present in at least one sample from at least one facility at a concentration that exceeds a relevant screening criterion. The conservative screening criteria used in this analysis are listed in Exhibit 2-3. Constituents that were not detected in a given sample were assumed not to be present in the sample.

- (b) Human health screening criteria are based on cancer risk or noncancer health effects. "Human health" screening criteria noted with an "n" are based on 1×10^{-5} lifetime cancer risk; others are based on noncancer effects.

Exhibit 12-5 (cont'd)
Potential Constituents of Concern in Phosphoric Acid Process Wastewater
(Total)^(a)

Potential Constituents of Concern	No. of Times Constituent Detected/No. of Analyses for Constituent	Screening Criteria ^(b)	No. of Analyses Exceeding Criteria/ No. of Analyses for Constituent	No. of Facilities Exceeding Criteria/ No. of Facilities Analyzed for Constituent
Boron	2 / 2	Resource Damage	1 / 2	1 / 1
Molybdenum	34 / 39	Resource Damage	27 / 39	10 / 10
Antimony	27 / 70	Human Health	10 / 70	6 / 14
Thallium	18 / 56	Human Health	18 / 56	5 / 13
Cobalt	35 / 41	Resource Damage	7 / 41	3 / 10
Silver	43 / 73	Aquatic Ecological	12 / 73	5 / 14
Mercury	45 / 74	Aquatic Ecological	6 / 74	4 / 14
Fluoride	53 / 53	Human Health Resource Damage	3 / 53 1 / 53	1 / 12 1 / 12
Zinc	77 / 77	Aquatic Ecological	9 / 77	3 / 14
Chloride	26 / 26	Resource Damage	2 / 26	1 / 6
Beryllium	66 / 71	Resource Damage	2 / 71	1 / 14
Selenium	56 / 73	Human Health Resource Damage Aquatic Ecological	1 / 73 2 / 73 2 / 73	1 / 14 1 / 14 1 / 14
pH	68 / 68	Resource Damage	59 / 68	13 / 14

- (a) Constituents listed in this table are present in at least one sample from at least one facility at a concentration that exceeds a relevant screening criterion. The conservative screening criteria used in this analysis are listed in Exhibit 2-3. Constituents that were not detected in a given sample were assumed not to be present in the sample.
- (b) Human health screening criteria are based on cancer risk or noncancer health effects. "Human health" screening criteria noted with an "h" are based on 1×10^{-5} lifetime cancer risk; others are based on noncancer effects.

Release, Transport, and Exposure Potential

This analysis evaluates the baseline hazards of phosphogypsum and phosphoric acid plant process wastewater as it was generated and managed at the 21 phosphoric acid facilities in 1988. It does not assess the hazards of off-site use or disposal of these wastes or the risks associated with variations in waste management practices or potentially exposed populations in the future because of a lack of data on off-site and projected future conditions.

EPA has identified a variety of documented cases of dangers posed by the release of constituents from these wastes to the environment, and EPA's Office of Air and Radiation (OAR) has studied air pathway risks (from radionuclides) posed by these wastes. Consequently, the Agency has used information on documented and potential damages from these other analyses to support its evaluation of the release, transport, and exposure potential of the current management of these wastes.

Ground-Water Release, Transport, and Exposure Potential

Section 12.3.2 describes documented cases of ground-water contamination at seven phosphoric acid plants located in Central Florida (3), Louisiana (2), North Carolina (1), and Idaho (1). These cases indicate that phosphogypsum and process wastewater constituents have been released to ground water at a number of facilities and, at some sites, have migrated off-site to potable wells in concentrations that are well above hazard criteria. Based on the analysis of the damage case evidence, presented below, EPA concludes that management of phosphogypsum and process wastewater in stacks and ponds can release contaminants to the subsurface, and depending on the hydrogeologic setting and ground-water use patterns, threaten human health via drinking water exposures or render ground-water resources unsuitable for potential use.

In the following paragraphs, EPA presents a region-by-region assessment of the hazards posed by phosphogypsum and process wastewater management. For purposes of this discussion, phosphoric acid plants are grouped into the following eight regions: Central Florida, North Carolina, Louisiana, Idaho, North Florida, Mississippi, Texas, and Wyoming. For each region for which ground-water damages have been documented, the Agency first builds the case that damages attributable to waste management have occurred, then, to the extent necessary, uses environmental setting information to assess the potential hazards (i.e., health risks and resource damage potential) at other facilities in the region. When no damage case information is available for a region, evidence of release potential is used in conjunction with environmental setting information to assess the hazards of potential releases from the plants in these regions.

Central Florida. The Florida Department of Environmental Regulation has initiated enforcement actions in response to ground-water contamination associated with the management of phosphogypsum and process wastewater at all 11 active phosphoric acid production facilities in Central Florida. At three of these facilities (i.e., Central Phosphates, Seminole, and IMC) contamination of the useable intermediate or Floridan aquifers exceeds primary drinking water standards for pH, gross alpha radiation, radium, sodium, total dissolved solids, sulfate, cadmium, chromium, fluoride, and arsenic beyond the permitted zone of discharge.⁷ With the exception of sodium and total dissolved solids, all of these constituents were identified as potential constituents of concern in phosphogypsum or process wastewater. At the other eight facilities, contamination exceeding drinking water standards beyond the permitted zone of discharge has been detected only in the surficial aquifer. Two of the three damage cases for Central Florida phosphoric acid production plants presented in Section 12.3.2 (i.e., Central Phosphates and Seminole) discuss contamination of off-site ground water in formations that are used for water supplies. At Central Phosphates, a ground-water contamination plume in the Floridan aquifer extends six acres beyond the facility boundary; contamination of the surficial aquifer covers 28 acres outside the facility boundary. Twelve of 18 potable supply wells down-gradient of the Seminole plant sampled in 1988 contained at least one constituent at a concentration in excess of a drinking water standard. The owner of the phosphoric acid plant paid to have the affected properties connected to a public water supply. These ground-water contamination incidents indicate a high potential for ground-water releases from the phosphoric acid production plants in Central Florida. Except for the Gardinier facility, all operating plants in this area are within 1,000 meters of a public supply well and contamination of the Floridan aquifer at these sites could pose a public health threat via drinking water exposures. As demonstrated by the damage cases and violations of drinking water standards beyond the permitted zone of discharge, contaminants from these wastes can reach the useable aquifer in this area and migrate down-gradient toward potential exposure points.

North Carolina. Section 12.3.2 discusses ground-water contamination resulting from management of process wastewater at the phosphoric acid plant in Aurora, North Carolina. The extent of ground-water contamination at this site is not known with certainty, but fluoride and total dissolved solids concentrations in on-site wells exceed state drinking water standards in the surficial aquifer that is not extensively used and in an intermediate aquifer that is useable,

⁷ The State of Florida allows discharges to ground water within a defined "zone of discharge." The horizontal extent of the zone typically is limited to the property boundary.

but not developed in the vicinity of the site. No contamination has been detected in a deeper aquifer that serves as the principal water supply in this area. Although off-site migration of contaminants and contamination of the principal water supply aquifer have not been documented, exposures could occur if contaminated drinking water were withdrawn from the surficial aquifer at nearby residences (as close as 100 meters). Even though ground water in the surficial and intermediate aquifers is not currently used as a drinking water source, the documented contamination may render ground water beneath the facility, and possibly down-gradient of the facility, unsuitable for potential future uses.

Louisiana. Documented cases of ground-water damages from phosphogypsum and process wastewater management at two plants in Louisiana are presented in Section 12.3.2. Data provided in the damage cases indicates that ground water beneath the Geismar facility is contaminated with gross alpha radiation at concentrations more than six times the federal primary drinking water standard. In addition, the Louisiana Department of Environmental Quality concluded in 1986 that "contamination of the shallow ground water [at Donaldsonville], although by constituents which are not of great concern, poses a threat to drinking water."⁸ Current human health threats via drinking water at the Donaldsonville and Geismar facilities are unlikely because there are no private residences or public wells that derive drinking water supplies within 1,600 meters (1 mile) down-gradient of these facilities. However, ground-water releases are also likely at the third active Louisiana plant (Uncle Sam), and potential exposures to contaminated ground water could occur at a residence located 180 meters down-gradient from this facility.

Idaho. One of the two phosphoric acid plants in Idaho is discussed in a damage case in Section 12.3.2. Although this damage case does not provide conclusive evidence of long-term ground-water contamination from releases of phosphogypsum and process wastewater, data presented indicate that a few constituents of concern for these wastes (e.g., selenium, manganese, sulfate, and phosphate) may be contaminating ground water down-gradient of the Caribou facility. Because of relatively high levels of background contamination, a recent geophysical survey at Caribou did not delineate a ground-water contamination plume originating at the plant. Nevertheless, selenium concentrations exceed federal secondary drinking water standards at on-site and down-gradient off-site production wells, and phosphate concentrations at a down-gradient off-site production well exceed background levels by a factor of 170. Both of these constituents are found in process wastewater, and a recent EPA site inspection report concludes that the ground-water monitoring data "suggest that some leakage from the [process wastewater] cooling pond may be occurring presently."⁹ In addition to this evidence of continuing contamination of the useable aquifer, the Caribou damage case discusses a spill of process wastewater, resulting from a dike failure, that contaminated off-site ground water with cadmium (at a concentration more than four times the federal drinking water standard), phosphate, and fluoride. Consequently, EPA concludes that typical management of phosphogypsum and process wastewater in Idaho may allow the continuous seepage of contaminants to ground water, and mismanagement (i.e., spills) of process wastewater has caused ground-water contamination. Any ground-water contamination that does occur as a result of waste management at the two Idaho facilities could pose human health threats at residences located 240 and 850 meters down-gradient of the Caribou and Pocatello plants, respectively.

North Florida and Mississippi. Although not demonstrated in the documented damage cases, ground-water contamination potential also appears to be relatively high at the plants in North Florida and Mississippi. As with the Central Florida facilities, the White Springs facility in North Florida is in karst terrane (characterized by sinkholes and underground cavities developed by the dissolution of carbonate rock such as limestone) which creates the potential for contaminant transport with limited dilution. Releases at this plant could result in exposures at a residence located 180 meters down-gradient. Ground-water contamination potential appears high at the Pascagoula plant in Mississippi because ground water occurs at a depth of only 1.5 meters in this area. Human populations are not likely to be exposed

⁸ Louisiana Department of Environmental Quality. 1986. Letter from George H. Cramer, II, Administrator to Susan Stewart, Agricola Manager Energy and Environmental Control, Re: Hydrogeologic Assessment, Final Report GD-093-0791.

⁹ EPA Region 10. 1988. Site Inspection Report to Nu-West Industries. Conda Plant, Caribou, Idaho. TDD F10-8702-08.

to potential ground-water contaminants at this facility, however, because currently there are no residences or public supply wells within 1,600 meters down-gradient from the facility.

Texas and Wyoming. The potential for ground-water pathway risks at the Texas and Wyoming facilities is relatively low. Releases from the management units at the plant in Pasadena, Texas are limited to some extent because the stack at this facility is lined with recompact local clay, and exposures to existing populations are unlikely because there is no residence or public supply well within 1,600 meters down-gradient from the facility. Similarly, the facility in Rock Springs, Wyoming poses a relatively low risk because its stack has a synthetic liner and the nearest down-gradient residence is quite distant (greater than 1,600 meters).

Surface Water Release, Transport, and Exposure Potential

The potential for the release of contaminants from phosphogypsum stacks and process wastewater ponds to surface water is also demonstrated by the damage cases presented in Section 12.3.2. These cases indicate that phosphogypsum and process wastewater management at plants in Central Florida, North Carolina, and Louisiana has resulted in the release of waste constituents to surface waters. Based on the analysis of the damage case evidence, it is clear that management of phosphogypsum and process wastewater in stacks and ponds can, and does, release contaminants to nearby surface waters. Depending on the distance to surface waters, the hydrogeologic setting, and surface water use patterns, EPA concludes that there is a potential for these released contaminants to migrate off-site and threaten human health via drinking water exposures, threaten aquatic life, or render surface water resources unsuitable for potential consumptive uses.

In the following paragraphs, EPA presents a region-by-region assessment of the hazards to surface water quality posed by phosphogypsum and process wastewater management. For each region for which surface water releases have been documented, the Agency first builds the case that releases from waste management units have occurred in the past and are typical of current practices, then uses environmental setting information to assess the potential hazards (i.e., health risks, risk to aquatic organisms, and resource damage potential) at other facilities in the region. When no damage case information is available for a region, evidence of release potential is used in conjunction with environmental setting information to assess the hazards of potential releases from the plants in these regions.

Central Florida. The damage cases presented in Section 12.3.2 indicate that unpermitted discharges of process wastewater and/or phosphogypsum stack seepage to surface waters have occurred at the Gardinier and Seminole plants in Central Florida. At the Gardinier facility, a number of releases from 1984 to 1988 have been documented. Releases to surface water from solid waste management at this plant arise from the discharge of untreated stack seepage from a drain system that is designed to intercept and collect leachate and effluent flowing laterally away from the stack. As indicated in the damage cases, fluorides, phosphorus, and radioactive substances are present at concentrations of concern in the effluent from this drain system. In addition, these unpermitted discharges had a pH of 1.5 to 2.2. In 1988, county and state inspectors discovered damaged vegetation on the shoreline of Hillsborough Bay along the west side of the gypsum stack where an unpermitted discharge was occurring. The affected area -- approximately one-half acre of saltwater marshes and wax myrtle -- had turned a brownish color,¹⁰ presumably as a result of the discharge of untreated stack seepage. At the Seminole facility, surface water contamination has occurred via an unpermitted discharge to Bear Branch. Similar releases, or releases of contaminated ground-water discharging to surface water, could also occur at the eight other facilities in this area that are located near surface waters. At two of these facilities (i.e., Central Phosphates and IMC), the nearby river is used as a source of drinking water downstream of the facility and releases to these rivers could pose a human health threat via drinking water exposures. Of the 11 active Central Florida plants, only Royster/Mulberry is not within 1,000 meters of surface water and is unlikely to pose a threat to surface water resources.

¹⁰ Hillsborough County Environmental Protection Commission. October 6, 1988. Memorandum from Roger Stewart, Director, to Pam Iorio, Commissioner.

North Carolina. As at the Gardinier plant, unpermitted discharges of stack drainage and process wastewater from the plant in Aurora, North Carolina are also associated with failure of the drain system designed to collect seepage at the foot of the gypsum stacks. In two separate incidents in 1980 and one in 1987, concentrations of fluoride and phosphorus released from the plant exceeded permit limits as a result of drainage ditch and dike failure and drain overflow. In the 1987 episode, the pH of a freshwater canal was below 6.0 for two hours and 18 dead fish were discovered in the week following the release. Based on this evidence, the Agency concludes that episodic releases from the phosphogypsum stack and ponds at this facility were not adequately controlled by run-on/run-off controls and collection of stack seepage. In addition, contaminants released to ground water may discharge to the Pamlico River and to the creeks in the vicinity of the site where they may endanger aquatic life.

Louisiana. Two documented cases of surface water damages from phosphogypsum and process wastewater management in Louisiana are presented in Section 12.3.2. At both the Donaldsonville and Geismar plants, releases occurred as a result of the emergency discharge of untreated water from gypsum stacks and ponds to surface waters. As noted in the damage cases, the facility operators claimed that these discharges were necessitated by excess precipitation that threatened to cause stack failures. Emergency discharges are permitted at facilities on the lower Mississippi during periods of excess precipitation. As discussed above, ground-water contamination potential is also significant at the three facilities in Louisiana, and ground water discharging to surface waters may provide another means of contaminant release. The threats posed by releases to surface waters in Louisiana may be limited somewhat by the large flow of the Mississippi River. Because the Mississippi River is not used as a source of drinking water directly downstream of the three phosphoric plants, releases from these plants do not pose any current human health threats.

Based on the evidence presented above, EPA concludes that constituents of phosphogypsum and process wastewater that are managed near surface water bodies are likely to be released to nearby surface waters as a result of stack failures, drain failure, and possibly ground-water seepage. The facilities in Pasadena, Texas; Pascagoula, Mississippi; and White Springs, Florida (north) are located close to surface waters and receive relatively large quantities of precipitation. Consequently, these plants may present a hazard to surface water similar to that of the Louisiana and Central Florida facilities. The surface water contamination potential at the plant in Pocatello, Idaho is somewhat lower because the small amount of precipitation limits ground-water recharge and the possibility of stack failure due to excess precipitation, but contamination of the Portneuf River (located only 240 meters away) may occur. Surface water contamination is unlikely at the plants in Rock Springs, Wyoming and Caribou, Idaho because of the relatively small amounts of annual precipitation (i.e., 20 to 35 cm/year) and the large distances to the nearest surface water (370 to 2,600 meters).

Air Release, Transport, and Exposure Potential

Air pathway hazards associated with phosphogypsum and process wastewater relate primarily to the emission of radon gas from the radioactive decay of radium found in these wastes and the emission of particulate matter resulting from the disturbance of the phosphogypsum stack surface.

In support of a rulemaking on national emission standards for radionuclides, EPA's Office of Air and Radiation (OAR) has assessed the risks of radon emissions from phosphogypsum stacks.¹¹ In this risk assessment, OAR estimates that the lifetime cancer risk to the maximally exposed individual (MEI) caused by the inhalation of radon in the vicinity of a phosphogypsum stack is 9×10^{-5} . The MEI lifetime cancer risk from radon inhalation is greater than or equal to 1×10^{-5} at 17 of the 21 active phosphoric acid facilities. Only the plants in Pascagoula, Mississippi; Aurora, North Carolina; Rock Springs, Wyoming; and White Springs, Florida have an estimated MEI lifetime cancer risk from radon inhalation of less than 1×10^{-5} .

Because phosphogypsum forms a crust on inactive areas of the stack as it dries, and because the active areas of the stack are moist, the emission of particulate matter by wind erosion is not thought to be a significant release

¹¹ U.S. EPA, 1989, Risk Assessments: Environmental Impact Statement for NESHAPS Radionuclides, Volume 2 (Background Information Document), Office of Radiation Programs.

mechanism.¹² Physical disturbance of dried phosphogypsum (e.g., by vehicles driving over the stacks), however, may be an important particle release mechanism. The OAR risk assessment estimated that the lifetime cancer risks from radionuclides in particle emissions from stacks range from 8×10^{-8} to 2×10^{-6} . Based on these risk estimates, the OAR assessment concludes that the risk from inhaling radon emitted from phosphogypsum stacks is approximately two orders of magnitude greater than the cancer risk posed by the inhalation of fugitive dust from phosphogypsum stacks.

The OAR study did not investigate the cancer risk posed by other toxic constituents (i.e., arsenic and chromium) in phosphogypsum via particle inhalation. To supplement OAR's radiological assessment, EPA performed a screening level analysis of the risks posed by arsenic and chromium blown from phosphogypsum stacks. Using typical concentrations of arsenic and chromium in phosphogypsum, EPA calculated a lifetime cancer risk of 7×10^{-7} from exposure to these constituents in windblown phosphogypsum.¹³ This analysis shows that the risk posed by arsenic and chromium in inhaled phosphogypsum particles is on the order of 35 percent of the risk posed by radionuclides in inhaled particles.

Based on these findings, the Agency concludes that phosphogypsum stacks pose a considerable air pathway cancer risk primarily as a result of radon emissions from the stacks. By summing the risk estimates for radon inhalation, radionuclides in phosphogypsum particles, and arsenic and chromium in particles, EPA estimates a total air pathway lifetime MEI cancer risk of approximately 9×10^{-5} from exposure to phosphogypsum constituents. This risk is primarily from inhalation of radon emitted from stacks (9×10^{-5}) with minor contributions from the inhalation of phosphogypsum particles containing radionuclides (2×10^{-6}) and arsenic and chromium (7×10^{-7}). Based on the OAR estimates of risk from radon emitted from the stacks, the following plants appear to pose the greatest air pathway risks: Pasadena, Texas; Royster/Palmetto; Uncle Sam, Louisiana; Seminole; Central Phosphate; and Caribou, Idaho. As mentioned above, the stacks at Pascagoula, Mississippi; Aurora, North Carolina; Rock Springs, Wyoming; and White Springs, Florida pose lower MEI lifetime cancer risk (i.e., $< 1 \times 10^{-5}$).

Proximity to Sensitive Environments

Eighteen of the 21 active U.S. phosphoric acid plants are located in or near environments that are vulnerable to contaminant release or that have high resource value. In particular:

- The Seminole facility reported in its response to the National Survey on Solid Wastes from Mineral Processing Facilities that it is located in an endangered species habitat.
- The Royster/Palmetto and Pascagoula facilities are located within 6.5 and 7.8 miles, respectively, of the critical habitat of an endangered species. The two endangered species are the Florida Manatee and the Mississippi Sandhill Crane. Because of the relatively large distance to these protected areas, the potential for impacts on the species or their critical habitat is quite low.
- Eight plants (i.e., Geismar, CF Chemicals, Gardinier, Pocatello, Pasadena, Pascagoula, Seminole, and Aurora) are located in 100-year floodplains. Management of wastes in floodplains creates the potential for large, episodic releases caused by flood events. (The effectiveness of flood control structures at these plants is not known.)
- The Gardinier, Pascagoula, and Aurora plants are located in a wetland (defined here to include swamps, marshes, bogs, and other similar areas). The Agrico/Mulberry, Geismar, Central Phosphates, CF Chemicals, Conserv, Royster/Palmetto, Farmland, Fort Meade, IMC, Caribou, White Springs, Royster/Mulberry, and Seminole plants are located within one mile of a wetland. Wetlands are commonly entitled to special protection because they provide habitats for many

¹² *Ibid.* p. 13-2.

¹³ This risk estimate is based on a comparison of the dust inhalation risks posed by (1) median arsenic and chromium concentrations as determined by EPA's data base developed for this study and (2) average concentrations of radium-226, uranium-234, uranium-238, thorium-230, polonium-210, and lead-210 presented in the OAR analysis. To calculate the relative risks posed by these constituent concentrations, EPA assumed an exposure point concentration of windblown phosphogypsum in air, and applied standard cancer slope factors and exposure assumptions, such as those used in developing the screening criteria (see Section 2.2.2), to estimate the relative contributions of carcinogenic metals and radionuclides to the inhalation risks posed by airborne phosphogypsum.

forms of wildlife, purify natural water, provide flood and storm damage protection, and afford a number of other benefits. Although the location of wetlands relative to potential contaminant sources is unknown, if contaminants released to surface water and ground water migrate to wetlands, the water quality degradation may adversely affect the wetland.

- The Pocatello facility is located in a fault zone. Wastes managed in a fault zone may be subject to episodic releases due to earthquake-induced failure of containment systems or berms.
- The Central Phosphates and Royster/Palmetto facilities are located in an area of karst terrain characterized by sinkholes and underground cavities developed by the dissolution of carbonate rock. Solution cavities that may exist in the bedrock at this site could permit any ground-water contamination originating from the wastes to migrate in a largely unattenuated and undiluted fashion.

Risk Modeling

Based upon the evaluation of intrinsic hazard and the descriptive analysis of factors that influence risk presented above, EPA has concluded that the potential for phosphogypsum and process wastewater from phosphoric acid production to impose risk to human health or the environment is significant, if managed according to current practice. As discussed above,

- Phosphogypsum and phosphoric acid process wastewater contain a number of constituents at concentrations that exceed conservative screening criteria, phosphogypsum occasionally contains chromium concentrations in excess of the EP toxicity regulatory level, and process wastewater regularly exhibits the RCRA hazardous waste criterion for corrosivity (i.e., pH below 2.0) and exceeds EP regulatory levels for cadmium, chromium, and selenium.
- Ground-water contamination from phosphogypsum stacks and process wastewater ponds has occurred or is likely at almost all plants, and, at some sites, contamination has reached off-site wells at levels above drinking water standards.
- Episodic and continuous releases of pond and phosphogypsum stack waters to surface water occur at a number of plants, and aquatic organisms have been adversely affected by these releases.
- Radon emissions from phosphogypsum stacks and windblown phosphogypsum particles are estimated to present a lifetime cancer risk to maximally exposed individuals of almost 1×10^{-4} .

Because of the weight of the empirical and analytical evidence summarized above, the Agency did not conduct a quantitative risk modeling exercise addressing these wastes. Section 12.3.3 provides a more detailed discussion of the Agency's conclusion that current management of phosphogypsum and phosphoric acid process wastewater poses a significant hazard.

12.3.2 Damage Cases

EPA conducted waste management case studies to assess the impacts of phosphogypsum and process wastewater management practices on human health and the environment. This review included 21 active and eight inactive phosphoric acid facilities. The inactive facilities are: Agrico, Hahnville, LA; Agrico, Fort Madison, IA; Albright & Wilson, Fernald, OH; JR Simplot, Helm, CA; Mobil Mining & Minerals, De Pue, IL; U.S. Agri-Chemicals Corp., Bartow, FL; Waterway Terminals, Helena, AR; and MS-Chemical located in Pascagoula, Mississippi. Documented damages attributable to management of phosphogypsum or process wastewater have been documented at more than ten facilities. Selected facilities are discussed in detail below.

Several factors play an important role in influencing the effectiveness of typical phosphogypsum and process wastewater management practices. Among these are water balance and soil stability. In Florida, for example, phosphogypsum dewatering and reduction of wastewater volumes are made possible due to the climate, specifically the relative amounts of precipitation and evaporation, in this region. In other areas, however, such as Louisiana, a net

precipitation surplus necessitates a system dependent on planned discharges to surface waters. Soil stability appears to be much greater in Florida as well, where gypsum may be stacked to heights up to 60 meters (200 feet). In Louisiana, gypsum piles over 12 meters in height are generally considered unstable. In light of these differences, the case studies presented in this section are grouped by state.

Idaho

Nu-West Industries-Conda, Soda Springs, Idaho

The Nu-West plant is located approximately five miles north of Soda Springs, Idaho, near the abandoned mining town of Conda. The site covers approximately 650 hectares (1,600 acres). With the exception of a period from 1985 to 1987, the plant has been in operation since 1964.

Currently, Nu-West formulates and markets phosphate-based chemicals and fertilizers. The phosphogypsum waste is a by-product of the digester system, which produces ortho-phosphoric acid (P_2O_5) from phosphate ore. Gypsum is slurried with process water and pumped to two storage ponds on top of the gypsum stacks, which have been in use since 1964 and presently cover approximately 240 to 280 hectares (600 to 700 acres). The gypsum ponds are unlined; the stacks are about 46 meters (150 feet) above the natural ground surface. Drainage systems decant slurry water off the top of the higher ponds into ponds at lower elevations.

During March 1976, a dike surrounding the Nu-West cooling pond failed and released 400 acre feet of wastewater into the surrounding area. The water spread out and ponded on an estimated 20 to 40 hectares (50 to 100 acres) of farm land. The water then migrated via a natural drainage path, forming a small river that extended four miles to the south. Wastewater reportedly infiltrated into local soil and underlying bedrock along its overland migration path, but never entered a natural surface water body.

While the Idaho Division of Environment determined that dilution during spring run-off reduced surface concentrations of contaminants to within acceptable limits, the Caribou County Health Department recorded significant increases in ground-water concentrations of phosphate, cadmium, and fluoride immediately following the spill. Samples from a J.R. Simplot Company (Conda Operation) production well No. 10, located down-gradient from the Nu-West facility, show that before the spill occurred, levels of phosphate in the ground water averaged 100 mg/L, and rose to 1,458 mg/L after the spill. Levels of cadmium in the ground water averaged 0.01 mg/L before the spill and 0.239 mg/L after the spill, and levels of fluoride averaged 5 mg/L before, and 39 mg/L after, the spill, respectively.¹⁴

In 1987, EPA Region X conducted a file review and site inspection of Nu-West. This inspection included ground-water sampling, aqueous and solid sampling from the waste ponds, and a geophysical survey. A total of six ground-water samples were collected: two from on-site industrial production wells (MF well, PW. No. 1); two off-site industrial production wells (Simplot No. 11, Simplot No. 10); and, two domestic wells in the site area. Results of the Nu-West site inspection were published in a site inspection report in March, 1988. Selenium exceeded Federal Primary Drinking Water Standards in all of the production well samples. Manganese and sulfate exceeded Federal Secondary Drinking Water Standards in Simplot Well No. 10. Phosphate was detected at 8.2 mg/L in Simplot Well No. 10, a level approximately 30 times greater than that found in the MF well and 170 times greater than that found in the background well (Simplot Well No. 11). A total of eleven target compound list (TCL) inorganic elements were detected in at least one of the domestic well samples; however, none of the sample concentrations exceeded Federal Primary or Secondary Drinking Water Standards.¹⁵

The geophysical survey results indicated that there was no significant difference between the background and on-site values obtained from the survey. However, as stated in the EPA Site Inspection Report: "There are seven registered domestic wells within a three mile radius of the Nu-West site, serving an estimated 27 people. Total depths

¹⁴ EPA Region 10. 1988. Site Inspection Report to Nu-West Industries Conda Plant, Caribou, Idaho. TDD F10-8702-08. March, 1988.

¹⁵ *Ibid.*

of these wells range between 90 feet to 245 feet below ground surface. Eleven registered industrial production wells exist on and near the Nu-West site, one of which provides drinking water for approximately 45 J.R. Simplot employees in Conda (Simplot #11). At the time of the [EPA] inspection, Nu-West employees consumed bottled water due to poor water quality of the only well in use at the site (MF well)."¹⁶

The EPA Site Inspection Report concludes by stating: "Levels of TCL inorganic elements and anions detected in the groundwater samples during the [EPA] site investigation were similar to those obtained by the Caribou County Health Department during non-spill event time periods. However, the levels detected during the [EPA] site investigation should not be considered indicative of stable long-term groundwater quality conditions at the site. [Data show] that significant increases in groundwater contaminant concentrations have occurred as a result of a past spill at the Nu-West facility. Although survey results are inconclusive, the data suggest that some leakage from the cooling pond may be occurring presently. If leakage from the cooling pond increases as a result of pond aging or increased water circulation, a contaminant plume may develop and migrate to the south-southwest."¹⁷

Florida

Gardiner, Inc., in East Tampa, Florida

Gardiner, Inc.'s East Tampa Chemical Plant Complex encompasses about 2,600 acres of land and is located in west-central Hillsborough County, Florida. The facility is located at the mouth of the Alafia River adjacent to Hillsborough Bay. The plant began its operations in 1924 and has been expanded several times by various owners. In 1973, Gardiner, Inc. took over the entire operation. Gardiner, Inc. is owned by Cargill, Inc. of Minneapolis, Minnesota. Operations currently include production of phosphoric acid and phosphate and other fertilizers.^{18,19}

Gardiner's on-site waste management units include two process water ponds (Nos. 1 and 2) and a gypsum stack. Process Water Pond No. 1 is an unlined pond that occupies 13 hectares (32 acres) and is 2 meters (6 feet deep); Process Pond No. 2 occupies 80 hectares and is 2.1 meters deep. The gypsum stack, which as of December 31, 1988 contained about 58 cubic meters (76 million cubic yards) of material, occupies an area of 150 hectares and is 61 meters high. The ponds on top of the gypsum stack occupy 16 hectares and are 2 meters deep. The typical pH of the liquid in the gypsum stack ponds is 1.8.²⁰

Phosphogypsum is piped to the gypsum stack as a slurry mixture (approximately 30 percent solids). The gypsum settles from the slurry and the liquid is decanted for reuse in the manufacturing process. Water which seeps through the stack is collected in a perimeter drain that is buried at the toe of the stack. The drain carries the seepage water to a sump in the northeast corner of the gypsum stack where it is pumped to an evaporation pond located on part of the gypsum stack. Surface water run-off from the exterior slopes of the stack is discharged into Hillsborough Bay.²¹

¹⁶ EPA Region 10. 1988. Site Inspection Report to Nu-West Industries Conda Plant, Caribou, Idaho. TDD F10-8702-08. March, 1988.

¹⁷ Ibid.

¹⁸ Ardaman & Associates, Inc. September 23, 1983. Groundwater Monitoring Plan for East Tampa Chemical Plant Complex, Hillsborough County, Florida.

¹⁹ Ibid.

²⁰ Gardiner, Inc. March 29, 1989. National Survey of Solid Wastes from Mineral Processing Facilities.

²¹ Ardaman & Associates, Inc. September 23, 1983. Groundwater Monitoring Plan for East Tampa Chemical Plant Complex, Hillsborough County, Florida.

Records at the Hillsborough County Environmental Protection Commission (HCEPC) cite environmental incidents at the Gardinier facility as far back as November 21, 1973, when HCEPC investigated a citizen's complaint and discovered 210 dead crabs in traps placed near the facility's northwest outfall. The pH of the outfall water was 2.9.^{22,23}

Water quality violations attributable to Gardinier resulted in the following administrative actions: a Consent Order negotiated between the HCEPC and Gardinier on August 22, 1977; a Citation to Cease Violation and Order to Correct from HCEPC on November 8, 1984; a Warning Notice from the State of Florida Department of Environmental Regulation (FDER) on April 9, 1987; a Citation to Cease and Notice to Correct Violation from the HCEPC on May 26, 1988; and, a Warning Notice from FDER on October 18, 1988. These administrative actions were issued to Gardinier following unpermitted discharges from either the gypsum stack or the cooling water ponds.

The November 8, 1984 citation was issued for an untreated effluent discharge which occurred on October 8, 1984. The citation notes that "toe-drain effluent contains several thousand milligrams per liter of fluorides and phosphorus and up to 150 pico-curries per liter of radioactive substances. Also, its pH can be as low as 1.5 standard units."²⁴ A sample of the discharge on March 30, 1987, which resulted in the April 9, 1987 warning notice, shows that the pH was 1.9, total phosphorus was 6,740 mg/L and dissolved fluorides was 4,375 mg/L.²⁵ HCEPC analyzed a sample of the discharge which resulted in the October 18, 1988 warning notice and reported the following results: pH, 2.2; total phosphorus, >4,418 mg/L; and fluoride, 1,690 mg/L.²⁶

The May 26, 1988 citation from HCEPC states that "available agency records indicate a considerable history of incidents of discharge resulting in exceedances of environmental standards and contamination of the air and waters of Hillsborough County. Enforcement in each case required remedial actions intended to correct the effects of the discharge where appropriate, as well as design and maintenance measures to prevent reoccurrence of the same or like incident. Despite all efforts, such incidents continue to occur."²⁷

HCEPC records also include a Gardinier Air Complaints Summary which lists 78 citizen complaints about the facility from December 6, 1983 to May 10, 1988. The complaints were made about noxious odors, fumes, smoke, dust or mist from the facility. One of the complaints clearly identifies the gypsum stack as the source; the relationship of the other complaints to gypsum and water management systems at the facility cannot be determined from the available documentation. HCEPC responded to most of these complaints with a phone call or site visit. At least three of the site visits resulted in HCEPC issuing a warning notice to the facility.²⁸

Since 1985, Gardinier has monitored ambient air quality for radon and fluoride. In 1985, Gardinier reported its average radon-222 flux from the gypsum pile to be 21.6 pCi/square meter-second (the recently promulgated NESHAP specifies a limit of 20 pCi/m²-sec). Ambient fluoride was 0.43 ppb, with a maximum reading of 1.2 ppb.²⁹ Nonetheless,

²² Hillsborough County Environmental Protection Commission. May 6, 1988. Gardinier History.

²³ Hillsborough County Environmental Protection Commission. November 26, 1973. Interoffice Memo from Robert M. Powell to Richard Wilkins.

²⁴ Hillsborough County Environmental Protection Commission. November 8, 1984. Citation to Cease Violation and Order to Correct issued to Gardinier, Inc.

²⁵ Hillsborough County Environmental Protection Commission. March 31, 1987. Notice of Alleged Violation issued to Gardinier, Inc.

²⁶ Florida Department of Environmental Regulation. October 18, 1988. Warning Notice No. WN88-0001IW29SWD issued to Gardinier, Inc.

²⁷ Hillsborough County Environmental Protection Commission. May 26, 1988. Case No. 6169 WP. Citation to Cease and Notice to Correct Violation issued to Gardinier, Inc.

²⁸ Hillsborough County Environmental Protection Commission. Undated. Gardinier Air Complaints Summary.

²⁹ Gardinier, Inc. September 25, 1985. First Annual Report submitted to the Hillsborough County Administrator pursuant to Development Order 80-713.

Gardinier reported that no National Ambient Air Quality Standards or National Emissions Standards for Hazardous Air Pollutants were exceeded during 1988.³⁰

In addition to the impacts to surface water, biota, and air noted above, ground water at the facility has been affected by facility operations. Ground-water quality has been monitored quarterly at the facility for several years. Since January 1, 1984, standards for the following drinking water parameters were exceeded in wells located both up-gradient and down-gradient of the facility's special waste management units: chromium, radium-226 and radium-228, gross alpha, chloride, iron, manganese, pH, and total dissolved solids.³¹ Examination of data for the period 1987 through early 1989 indicates that several on-site wells in the shallow aquifer routinely exceeded the gross alpha primary drinking water standard by a factor of between 2 and 4; exceedances in the intermediate aquifer were also common, although less frequent and of lesser magnitude.

Central Phosphates, Plant City, Florida

The Central Phosphates, Inc. (CPI) Plant City Chemical Complex is located approximately 16 km (10 miles) north of Plant City. The facility occupies approximately 616 hectares (1,520 acres) of land.³² The site is underlain by a surficial aquifer and the Floridan aquifer. The surficial aquifer ranges in depth from .3 to 15 meters (one to 50 feet) and is recharged by local rainfall.³³ In the Floridan aquifer, the uppermost useable aquifer at the site, wells are generally cased to depths greater than 200 feet.³⁴ The principal uses of the water in the uppermost useable aquifers underlying the site are rural domestic, agricultural, and commercial/ industrial.³⁵

The CPI plant began operation in December 1965; principal products include phosphate fertilizer, sulfuric acid, and ammonia.³⁶ Phosphogypsum generated during the production of phosphoric acid is disposed onsite at the company's 170 hectare (410-acre) phosphogypsum stack. A 50 hectare unlined process water cooling pond completely surrounds the gypsum stack. The depth of the cooling pond is 2.4 meters (8 feet). As of December 31, 1988, the unlined gypsum stack was 111 feet high and contained approximately 70,000,000 tons of material. The top of the gypsum stack presently contains 8 ponding areas occupying a total area of approximately 105 hectares. Two designated areas on top of the stack, located in the middle, are used for disposal of non-hazardous waste materials, such as construction and demolition debris and non-hazardous chemicals.³⁷

Activities at the Central Phosphates site have resulted in ground-water contamination in the surficial and upper Floridan aquifers. To date, it has been determined that the surficial aquifer and, to an undetermined extent, the Floridan aquifer have increased levels of fluoride, sodium, gross alpha radiation, heavy metals, sulfate, total dissolved solids, and nutrient compounds in excess of applicable guidance concentrations and/or state and federal drinking water standards.

³⁰ Gardinier, Inc. March 29, 1989. "National Survey of Solid Wastes from Mineral Processing Facilities."

³¹ Ibid.

³² Ardaman & Associates, Inc., April 2, 1987, Geotechnical Evaluation and Design Recommendations for Proposed Gypsum Stack Expansion, Plant City Chemical Complex, Hillsborough County, Florida (part).

³³ Central Phosphates, Inc., March 29, 1989, "National Survey on Solid Wastes from Mineral Processing Facilities."

³⁴ Ardaman & Associates, Inc., August 9, 1988, Contamination Assessment Report, Central Phosphates, Inc., Plant City Phosphate Complex, Hillsborough County, Florida.

³⁵ Central Phosphates, Inc., March 29, 1989, "National Survey on Solid Wastes from Mineral Processing Facilities."

³⁶ Ardaman & Associates, Inc., September 21, 1987, Quality Assurance Project Plan, Central Phosphates, Inc., Plant City Phosphate Complex (part).

³⁷ Central Phosphates, Inc., March 29, 1989, "National Survey on Solid Wastes from Mineral Processing Facilities."

Contaminated ground water, primarily in the surficial aquifer, has migrated off-site under approximately 11 hectares (27.5 acres) of the Cone Ranch property, located south of the CPI facility.^{38,39}

Quarterly ground-water sampling began at the Central Phosphates facility in April 1985. Based on the results of sampling from these wells in the second quarter of 1985, a warning notice was issued to the facility by the Florida Department of Environmental Regulation (DER) for violation of the primary drinking water regulations. Maximum contamination levels for sodium and chromium were exceeded in a down-gradient well in the Floridan aquifer and for sodium, chromium, and fluoride in a down-gradient well in the surficial aquifer.⁴⁰

In June 1987 the West Coast Water Supply Authority provided DER with preliminary data from laboratory analysis of ground-water samples collected from the Cone Ranch property which indicated degradation of both the surficial and the upper Floridan aquifers.⁴¹

The final report on ground-water investigations conducted at Cone Ranch during May and June 1987, prepared by consultants to the West Coast Regional Water Supply Authority, identifies two areas of contamination on the Cone Ranch property. The report concludes that contamination in one area (designated Area A) was caused by a dike failure and resultant spill of process water from the Central Phosphates facility in 1969 and that contamination in another area (Area B) was caused by seepage of contaminated water from the recirculation pond located immediately north of the spill area.⁴²

A consent order addressing the ground-water contamination problems at the site was drafted by DER during July of 1987 and signed by DER and Central Phosphates, Inc. on September 29, 1987. The consent order documents violations of primary and secondary drinking water standards for chromium, sodium, fluoride, gross alpha radiation, lead, and cadmium from a down-gradient well in the surficial aquifer. These violations occurred from May 6, 1985 through April 27, 1987; maximum values listed in the consent order for each contaminant are as follows: chromium, 0.075 mg/L; sodium, 1700 mg/L; fluoride, 6 mg/L; gross alpha, 29 pCi/L; lead, 0.11 mg/L; and, cadmium, 0.022 mg/L. The consent order required Central Phosphates, Inc. to implement corrective measures and ground-water remediation at the site.⁴³

The Joint Water Quality/RCRA Overview Committee of the Florida Phosphate Council has recorded quarterly sampling data from the Central Phosphates, Inc. site from April 24, 1985 through January 18, 1989 for DER Well Nos. 1 through 6, as well as data from sampling in April 1988 for miscellaneous other wells located both on and off CPI property. These data show consistent exceedances of water quality standards in the down-gradient surficial aquifer for pH, iron, fluoride, manganese, total dissolved solids, and sulfate. Water quality standards for iron and total dissolved solids were consistently exceeded in the down-gradient upper Floridan aquifer.⁴⁴

The Contamination Assessment Report (CAR) for the CPI facility, prepared pursuant to the Consent Order, concurs with the assessment made by the West Coast Regional Water Quality Authority in its definition of two plumes of contaminated ground water which have migrated offsite. Area A was found to comprise an area of 6.3 hectares (15.5 acres) in the surficial aquifer and 2.4 hectares in the upper Floridan aquifer. The off-site areal plume within the surficial aquifer was found to extend approximately 150 meters (500 feet) south and 460 meters east of the CPI property. The plume in the surficial aquifer of Area B was found to extend approximately 150 meters south in the Cone Ranch property,

³⁸ West Coast Regional Water Supply Authority. May 11, 1989. Letter from M. G. Korosy, Hydrologic Services Manager, to M. Troyer, ICF, Inc.

³⁹ Ardaman & Associates, Inc., August 9, 1988, Contamination Assessment Report, Central Phosphates, Inc., Plant City Phosphate Complex, Hillsborough County, Florida.

⁴⁰ State of Florida, Department of Environmental Regulation, Warning Notice No. 29-85-07-182, July 17, 1985.

⁴¹ Case Chronology for Central Phosphates, Inc., undated, Florida Department of Environmental Regulation enforcement files.

⁴² Leggette, Brashears & Graham, Inc., July 15, 1987, West Coast Regional Water Supply Authority Hydrologic and Water Quality Site Investigation at Cone Ranch, Hillsborough County, Florida.

⁴³ Consent Order, September 29, 1987, between the State of Florida Department of Environmental Regulation and Central Phosphates, Inc.

⁴⁴ Florida Phosphate Council, Joint Water Quality/RCRA Overview Committee, 1989, Groundwater Sampling Data.

covering an area approximately 5 hectares.⁴⁵ Phase II of CPI's contamination assessment, due for completion in the near future, is to include definition of the lateral and vertical extent of contamination.⁴⁶

Seminole Fertilizer, in Bartow, Florida

The Seminole Fertilizer Corporation (formerly W.R. Grace & Company) Bartow Chemical Plant is located in central Polk County between the towns of Bartow and Mulberry. The plant began operation in 1954, and includes production facilities for phosphoric acid and phosphate and other fertilizers. The facility is underlain with three aquifers. The depth of the surficial aquifer ranges from 3 to 18 meters (10 to 60 ft). The intermediate aquifer ranges in depth from 18 to 61 meters. The typical depth at the facility to the uppermost useable aquifer (the Floridan) is approximately 61 meters.⁴⁷

Waste management facilities at Seminole include one wastewater treatment plant, nine surface impoundments, two landfills, and two phosphogypsum stacks. The wastewater treatment plant, which is a two-stage liming facility, is used only during unusually intense rainfall events. Two surface impoundments are associated with the wastewater treatment plant: surface impoundment No. 1 is the primary liming pond and surface impoundment No. 2 is the secondary pond. Surface impoundment No. 3 occupies approximately 1.3 million square feet and is used as a cooling pond for process wastewaters, while surface impoundments Nos. 4-6 are a series of interconnected cooling ponds. The pH of the process water in the cooling ponds varies from 1.8 to 2.3, due to seasonal rains. Surface impoundments Nos. 7-9 are old clay settling ponds. Of the facility's two landfills, only one is currently in use. Landfill No. 1, occupying approximately 11 hectares (28 acres), is closed. Landfill No. 2 occupies 5 hectares and is used for filter cloths and solid materials not pumped to the gypsum stack.⁴⁸

The north gypsum stack, which first received waste in 1954, occupies approximately 65 hectares (159 acres) at an average height of 9 meters (28 ft). This stack receives process wastewater, phosphogypsum, gypsum solids from "tank clean out," and filter cloths. As of December 31, 1988, the north gypsum stack contained 14 million short tons of material. The south gypsum stack, which first received waste in 1965, occupies approximately 164 hectares at an average height of 14 meters. As of December 31, 1988, the south gypsum stack had accumulated 38 million metric tons of material.⁴⁹

Activities at the Seminole Fertilizer Corporation facility have resulted in elevated levels of several parameters in ground water in the surficial and intermediate aquifers. This contamination has affected potable water wells in the area, some of which have been replaced with water from the City of Bartow's public supply.⁵⁰

Seminole maintains eight monitoring wells as part of the ground-water monitoring system required for its state permit. Seminole has stated that MW-3 and MW-7 are up-gradient, background wells. All other wells are listed as down-gradient. The facility's ground-water data from September 1986 through March 1989 show that the down-gradient wells repeatedly exceeded the water quality standards for pH, gross alpha radiation, radium-226 and radium-228, iron, manganese, TDS, sulfate, cadmium, chromium, lead, and fluoride.⁵¹

On March 8, 1988, the Florida DER issued a warning notice to W.R. Grace & Company for violations of its ground-water monitoring permit during the third and fourth quarters of 1987. The standards for gross alpha radiation,

⁴⁵ Ardaman & Associates, Inc., August 9, 1988, Contamination Assessment Report, Central Phosphates, Inc., Plant City Phosphate Complex, Hillsborough County, Florida.

⁴⁶ West Coast Regional Water, Supply Authority. 1990. Letter from M. Korosy to P. Bill, ICF, Re: Cane Beach Property, Hillsborough County, Florida; Draft Mineral Processing Waste Management Case Study on Central Phosphates, Inc., May 23.

⁴⁷ Seminole Fertilizer Corporation. March 27, 1989. "National Survey on Solid Wastes from Mineral Processing Facilities."

⁴⁸ *Ibid.*

⁴⁹ *Ibid.*

⁵⁰ Florida Department of Environmental Regulation. September 29, 1988. Conversation Record between B. Barker, Drinking Water Section, and K. Johnson, FDER.

⁵¹ Seminole Fertilizer Corporation. June 1, 1989. Copy of facility's ground-water monitoring data from 9/86 to 3/89.

radium-226 and radium-228, and sodium had been exceeded in some ground-water samples.⁵² The analytical results showed the following maximum concentrations for each parameter: gross alpha, 107 pCi/L; radium-226 & -228, 14.4 pCi/L; and, sodium, 657 mg/L.

In addition to on-site wells, neighboring potable water wells have also been adversely affected. Analytical data from May 1988 show that 12 of 18 wells contained at least one contaminant at levels above the drinking water standards. Contaminants that were found in the samples included arsenic, lead, sodium, gross alpha, radium-226 and radium-228, iron, pH, sulfate, and total dissolved solids.⁵³ Potable water wells near the facility were replaced by a public water supply from the City of Bartow; W.R. Grace apparently paid for the water supply line installation and connection to the affected water users.⁵⁴

Seminole has also received a warning notice from the Florida DER for an unpermitted discharge of process water from the facility to Bear Branch.⁵⁵

Florida - Other

Management histories similar to those described for the above Florida facilities have also been documented by the Florida DER for CF Chemicals, Inc. and Farmland Industries, Inc. in Bartow, FL, and for Conserv, Inc. in Nichols, FL.

North Carolina

Texasgulf Chemicals, in Aurora, North Carolina

Texasgulf's phosphate plant is located six miles north of Aurora, Beaufort County, North Carolina, near the Pamlico River. Since at least 1973, Texasgulf Chemicals Company, an unincorporated division of Texasgulf, Inc., has engaged in the production of calcined and dried phosphate rock, sulfuric acid, phosphoric and superphosphoric acid, and other phosphate fertilizer ingredients at the Aurora plant.⁵⁶

Waste management units include clay slurry settling ponds, two unlined cooling water ponds, gypsum stacks, and clay blend piles, which contain a mixture of clay and gypsum.

The process of purifying the ore involves the separation of very fine clay particles from the phosphate rock. The clays leave the separation process as a water based slurry that is referred to as "slimes." They are hydraulically transferred to settling ponds where the clear water fraction is separated and discharged. There are 5 settling ponds with discharges to South, Bond, and Long Creeks via 12 permitted outlets.⁵⁷

Two cooling water ponds are used to recirculate process water through the phosphoric acid and fertilizer manufacturing areas, where it is primarily used in acid dilution, cooling, gypsum slurrying, and operation of emission

⁵² Florida Department of Environmental Regulation. March 8, 1988. Warning Notice No. 53-88-03-061.

⁵³ W.R. Grace & Company. June 3, 1988. Letter from Glenn Hall, Environmental Engineer, W.R. Grace & Co., to Kirk Johnson, Florida Department of Environmental Regulation and ground-water monitoring data for private potable wells adjacent to the facility.

⁵⁴ Florida Department of Environmental Regulation. September 29, 1988. Conversation Record between Bob Barker, Drinking Water Section, and Kirk Johnson, FDER.

⁵⁵ Florida Department of Environmental Regulation. May 30, 1984. Warning Notice No. 53-84-05-327.

⁵⁶ NC-Environmental Management Commission (EMC). April 2, 1987. Findings and Decision and Civil Penalty Assessment.

⁵⁷ NC-Division of Environmental Monitoring (DEM). July 31, 1986. Memorandum from J. Mulligan to R.P. Wilms, Director, NC-DEM, Re: Texasgulf Chemicals Co., Beaufort County.

control devices. Pond No. 1, with a surface area of 49 hectares (120 acres), began operation in November 1966. Pond No. 2, with a surface area of 24 hectares, began operation in late 1973.⁵⁸

There are six gypsum stacks or piles located on the plant site. The stacks, which cover approximately 101 hectares, are surrounded by a ditch that returns excess water from the stacks to Pond No. 1. There are also a number of gypsum-clay blend piles (designated R-1, R-2, R-4, and R-5) on the site which are/were used in land reclamation activities.

The North Carolina Department of Environmental Management has recorded a number of incidents dating back to 1980 at the Texasgulf Chemicals Plant which may have resulted in negative environmental impact.⁵⁹ These incidents include violations of Texasgulf's effluent permit and spills from the facility. For example, violations of the effluent permit for daily maximum phosphorus and fluoride were recorded in 1980 on March 12, March 13, December 9, and December 11. Daily maximum permit limits are 9 mg/L for phosphorus and 10 mg/L for fluoride. Recorded concentrations for the four days ranged from 11 to 34 mg/L for phosphorus. Fluoride concentrations were 12 mg/L on March 12 and March 13. These violations occurred when contaminated wastewater from the toe ditch of the gypsum pile overflowed into the company's fresh water system. A spill of 150,000 cubic meters (40 million gallons) of gypsum stack decant water into a nearby fresh water canal occurred on January 4, 1987 when a retaining dike around one of the gypsum stacks failed. A 24-hour analysis of the canal water showed a pH drop to a low of 4.2, with a two-hour period when pH was below 6.0. At least 18 dead fish were counted along the canal.⁶⁰ The company was fined \$1,000 for the incident by the State of North Carolina.⁶¹

Recent investigations have focused on leakage from cooling ponds Nos. 1 and 2, which have resulted in ground-water contamination of the first two water-bearing zones at the site.⁶² In 1988, Texasgulf commissioned a Preliminary Contaminant Assessment for Cooling Ponds 1 and 2 in fulfillment of requirements for the renewal of a zero discharge permit. As part of this study, Texasgulf installed a total of 21 monitoring wells at the site in March and April of 1988. These monitoring wells included 10 wells at Cooling Pond No. 1, nine wells at Cooling Pond No. 2, and two background monitoring wells.⁶³

Initial ground-water samples, obtained from monitoring wells at each of the cooling ponds during April 1988, show the results for the surficial aquifer and the Croatan Aquifer, which underlies the surficial aquifer at the site.⁶⁴ These results are displayed in Exhibit 12-6.

The first zone appears to be discharging to the facility's main effluent canal, while the direction of ground-water flow in the next zone is toward the northeast and Pamlico Sound.^{65,66} Texasgulf subsequently began additional

⁵⁸ Texasgulf. July 21, 1988. Preliminary Contamination Assessment at Cooling Ponds No. 1 and 2, Texasgulf Inc. Phosphate Operations, Aurora, North Carolina.

⁵⁹ NC-DEM. February 25, 1986. Memorandum from R.K. Thorpe to J. Mulligan, Washington Regional Office, NC-DEM, Re: Texasgulf Chemicals Company, Beaufort County.

⁶⁰ NC-DEM. February 10, 1987. Memorandum from R.K. Thorpe to L.P. Benton, Jr., Deputy Director, NC-DEM, Re: Fish Kill, Texasgulf Chemicals Co.

⁶¹ NC-Environmental Management Commission (EMC). April 2, 1987. Findings and Decision and Civil Penalty Assessment.

⁶² Texasgulf. July 21, 1988. Preliminary Contamination Assessment at Cooling Ponds No. 1 and 2, Texasgulf Inc. Phosphate Operations, Aurora, North Carolina.

⁶³ *Ibid.*

⁶⁴ Texasgulf. July 21, 1988. Preliminary Contamination Assessment at Cooling Ponds No. 1 and 2, Texasgulf Inc. Phosphate Operations, Aurora, North Carolina.

⁶⁵ NC-DEM. December 13, 1988. Memorandum from B. Reid to A. Mouberry, Re: Texasgulf, Inc. Renewal of Permit No. 2982, Cooling Ponds Nos. 1 and 2.

⁶⁶ NC-DEM. January 17, 1989. Memorandum from R. Jones to C. McCaskill, Sup. State Engineering Review Unit, Permits and Engineering Branch, Re: Permit Renewal No. 2982 Cooling Ponds #1 and #2 Texasgulf, Inc.

investigations to delineate the extent of contamination.⁶⁷ Initial results appear to support the initial conclusion that contamination is confined to the upper two water-bearing zones and that the Yorktown formation has prevented downward migration of contamination.⁶⁸ Texasgulf's Remedial Action Plan is currently under review by the NC-DEM.⁶⁹

Louisiana

Agrico Chemical Co., Donaldsonville, Louisiana

AGRICCO Chemical Company's Faustina Works phosphoric acid plant, which is located in Donaldsonville, Louisiana, began operations in 1974. Approximately 68 residents inhabit land within one mile of the facility. Receiving waters are the Mississippi River and the St. James Bayou.

Gypsum waste is slurried with process wastewater to a stacking area, where the solids settle out, and the water drains into adjacent ponds or clearwells.

This facility has experienced problems with elevated concentrations of phosphorus, fluoride and acid pH levels in surface and ground waters. Emergency discharges of untreated waters to surface water have occurred periodically throughout much of the 1980s; contamination of the ground water was reported in 1986.

EPA Region VI has prohibited the discharge of gypsum into the Mississippi River. About 1983, Agrico requested a modification of its NPDES Permit from EPA to allow Agrico to discharge gypsum to the Mississippi River under certain conditions. Agrico argued that the 1973 impoundment design was based on Florida facilities, and that the Louisiana climate and soils are different. Agrico stated that the height

⁶⁷ NC-DEM. December 13, 1988. Memorandum from B. Reid to A. Mouberry, Re: Texasgulf, Inc. Renewal of Permit No. 2982, Cooling Ponds Nos. 1 and 2.

⁶⁸ NC-DEM. June 3, 1989. Memorandum from B. Reid to R. Smithwick, Re: Texasgulf, Inc. Remedial Action Plan Cooling Ponds No. 1 and No. 2.

⁶⁹ Ardaman & Associates. February 6, 1990. Letter from T.S. Ingra and J.E. Garlanger to W.A. Schimming, Texasgulf, Re: Response to Deficiencies Noted by DEM Concerning the Cooling Pond No. 1 and No. 2 Remedial Action Plan and Proposed Revised Remedial Action Plan, Texasgulf Phosphate Operations.

Exhibit 12-6a
Ground-water Quality at Cooling Ponds 1 and 2 in the Surficial
Aquifer Confined Sand Layer

Parameter	State Drinking Water Standard (mg/L)	Cooling Pond 1 (mg/L)	Cooling Pond 2 (mg/L)
Phosphorus (Total)	--	42.5 - 6,475	0.04 - 660
Fluoride	1.5	1.5 - 2,790	0.2 - 6.5
Chloride	250	151 - 189	20 - 228
Sulfate	--	3,648 - 4,337	ND - 3,586
Total Dissolved Solids	500	5,685 - 27,783	255 - 4,444

Exhibit 12-6b
Ground-water Quality at Cooling Ponds 1 and 2 in the Croatan
Aquifer Confined Shell Layer

Parameter	State Drinking Water Standard (mg/L)	Cooling Pond 1 (mg/L)	Cooling Pond 2 (mg/L)
Phosphorus (Total)	--	0.3 - 125	0.05 - 32
Fluoride	1.5	0.2 - 2.5	0.1 - 0.5
Chloride	250	32 - 184	11 - 71
Sulfate	--	374 - 2,447	2.9 - 436
Total Dissolved Solids	500	915 - 6,722	219 - 1,451

limitation meant that the original 240 hectares (600 acres), which would have lasted until about 1998 would now last only until 1989.⁷⁰

In addition, Agrico stated further that "[a]nother related consequence is that the amount of contaminated run-off produced will increase geometrically as the impoundment acreage expands....Of the alternatives considered, only the "River Disposal/Partial Impoundment" option represents a reasonable and environmentally feasible alternative." Agrico concluded that "the water imbalance problem caused by continued total impoundment would result in an increased potential for the release of contaminated water."⁷¹

⁷⁰ U.S. Environmental Protection Agency, Region 6. Undated. Report submitted by attorneys for Agrico Chemical Company, Kean, Miller, Hawthorne, D'Armond, McCowan & Jarman, and Hall, Estill, Hardwick, Gable, Collingsworth & Nelson, Re: Agrico Chemical Company, NPDES Permit LA0029769.

⁷¹ Ibid.

On April 15, 1983, a portion of Agrico's 62-foot gypsum stack failed structurally and released 230,000 cubic meters (60 million gallons) of water from its 40 hectare (100-acre) pond onto plant property.^{72,73,74} The spilled water was pumped to another gypsum holding stack; concern over the potential failure of this stack, however, led Agrico to discharge the untreated water to the Mississippi River over a period of several weeks. These discharges exceeded permit limits.^{75,76} After the pond failure, water of pH 2 was found flowing in an on-site drainage ditch at approximately 20 gpm into the St. James Bayou. The large volume of released water had destroyed a dam that controlled flow from the drainage ditch into the St. James Canal. Agrico reinstalled the dam on April 22, 1983, and transferred the low pH water still in the dammed section of the ditch back to the gypsum pond system. Agrico checked the water in St. James Canal, concluding that it did not seem affected by the low pH water discharged to it as a consequence of the April 15, 1983 gypsum pond failure.^{77,78}

Due to heavy rainfall, Agrico has continued to periodically perform emergency discharges of untreated stormwater from the clearwell, as occurred in March and again in June 1987. In its letter of notification, Agrico stated that "additional rain could result in catastrophic levee failure leading to loss of life, personal injury, or severe property damage."⁷⁹

In March 1986, Agrico reported to LA DEQ that the water along the length of the north and east phosphogypsum perimeter ditches might be "slightly impacted" by phosphate, sulfate, and fluoride.⁸⁰

In August 1986, Agrico submitted to LA DEQ a Hydrologic Assessment report for the Donaldsonville facility. LA DEQ regarded the reported situation as requiring corrective action: "Contamination of the shallow ground water, although by constituents which are not of great concern, poses a threat to drinking water. The Department's position is that the same physical characteristics that allow the contaminants to travel through the shallow silt faster than your theoretical model are present in the underlying clays."⁸¹

Even under non-emergency circumstances, Agrico has had difficulty keeping in compliance with NPDES permit limitations. In April 1987, an investigator reported that discharges from Agrico's inactive gypsum impoundment (Outfall 002) were in exceedance (up to 35 times) of permitted levels. However, the investigator determined that no action would be taken "until reissuance of new permit."⁸²

⁷² Agrico. 1983. Letter from R.A. Woolsey, Plant Manager to J. Dale Givens, Administrator DNR, Re: WPCD Inspection of the Faustina Facility on April 22, 1983.

⁷³ Louisiana DNR. May 11, 1983. Installation Inspection Forms, completed by Susan Stewart, Installation Representative.

⁷⁴ U.S. Environmental Protection Agency, Region 6. Undated. Report submitted by attorneys for Agrico Chemical Company, Kean, Miller, Hawthorne, D'Armond, McCowan & Jarman, and Hall, Estill, Hardwick, Gable, Collingsworth & Nelson, Re: Agrico Chemical Company, NPDES Permit LA0029769.

⁷⁵ Ibid.

⁷⁶ Louisiana DEQ. October 25, 1984. Memorandum from Patricia L. Norton, Secretary, to J. Dale Givens, Assistant Secretary, Re: Agrico Chemical Co.

⁷⁷ Agrico. April 29, 1983. Letter from R.A. Woolsey, Plant Manager to J. Dale Givens, Administrator DNR, Re: WPCD Inspection of the Faustina Facility on April 22, 1983.

⁷⁸ Louisiana DNR. May 11, 1983. Installation Inspection Forms, completed by Susan Stewart, Installation Representative.

⁷⁹ Agrico. June 17, 1987. Letter from R.A. Woolsey, Plant Manager to Myron O. Knudson, U.S. EPA Region 6 Director Water Management, Re: NPDES Permit Number: LA0029769. With attachment.

⁸⁰ Agrico. March 12, 1986. Letter from Susan P. Stewart, Manager, Energy and Environmental Control to Gerald Healy, Administrator, LA DEQ Solid Waste Division, Re: Agrico Phosphogypsum Site (P-0063) GD-093-0791.

⁸¹ Louisiana DEQ. August 22, 1986. Letter from George H. Cramer, II, Administrator to Susan Stewart, Agrico Manager Energy and Environmental Control, Re: Hydrogeologic Assessment, Final Report GD-093-0791.

⁸² U.S. Environmental Protection Agency, Region 6. 1986-88. NPDES Violation Summaries, from 10/18/86 - 4/12/88.

In August 1987, LA DEQ determined that Agrico could not comply with the Louisiana Water Discharge Permit System that had been effective since March 1987.⁸³ LA DEQ issued an Administrative Order to Agrico to allow the facility to temporarily discharge water from gypsum stacks until standards were met.^{84,85,86,87}

According to the LA DEQ, this facility has not experienced non-compliance or emergency release problems since those outlined in this section.

Arcadian, Geismar, Louisiana

This facility, formerly owned by Allied Chemical, has been operational since 1967. The plant is situated along the Mississippi River, in Geismar, Louisiana, northeast of the intersection of LA Highways 75 and 3115. Approximately 150 residents live within 1.6 km (1 mile) of the facility.⁸⁸ There are private drinking water wells within a 1.6 km radius of the facility.^{89,90} The water table occurs at 24 meters (80 feet) below the land surface in the wet season, and 30 meters in the dry season.⁹¹ The Mississippi River receives the discharges from this facility.

The phosphogypsum waste is slurried to the stack with process wastewater, which drains into a retention pond referred to as "the clearwell." There are four clearwells of differing sizes at the site, one of which is described as active. Six phosphogypsum stacks occupy the site as well, one or two of which appear to be active.

The effluent guidelines prohibiting discharge of process pollutants from a wet phosphoric acid facility were rescinded for the plants on the lower Mississippi due to poor soil stability and excess precipitation. EPA Region 6 described the condition as follows: "The withdrawal of the guidelines allowed the creation of the concept of active and inactive impoundments. The inactive impoundment drainage may be discharged directly to the receiving stream without limits provided no further wastes are sent to the inactive system and the discharge meets water quality standards."⁹²

Two major categories of contaminant release to the environment have occurred at this facility: radioactivity releases to the ground water and clearwell discharges causing excessive phosphorus and fluoride loadings, as well as elevated pH, to surface waters. A third area of concern is fluoride fugitive emissions from the clearwell.

Arcadian has installed numerous monitoring wells throughout the gypsum stack and clearwell areas. Arcadian's ground-water monitoring report for the second half of 1988 showed gross alpha radiation in well P4 at 95 ± 31 pCi/L and 60 ± 14 pCi/L in well P10.⁹³ The MCL for gross alpha radiation is 15 pCi/L. These releases are not extensively documented in the files reviewed; the documents reviewed did not discuss actions taken in response to the results presented.

The net surplus of precipitation in this region has prompted Arcadian to perform emergency discharges of excess water from its clearwell. Arcadian has justified this action by stating that until the NPDES permit effluent

⁸³ Louisiana DEQ. August 17, 1987. Inter-office Letter, from G.S. Chambers to D.J. Miller, Re: Faustina Plant - Administrative Order.

⁸⁴ Ibid.

⁸⁵ Louisiana DEQ Water Pollution Control Division. 1987-88. Administrative Order issued by DEQ.

⁸⁶ U.S. Environmental Protection Agency. September 8, 1987. NPDES Compliance Inspection Report.

⁸⁷ U.S. Environmental Protection Agency, Region 6. 1988. Administrative Order, Re: Agrico Chemical Company, Docket No. VI-87-1411.

⁸⁸ Arcadian. April 21, 1989. "National Survey on Solid Wastes from Mineral Processing Facilities."

⁸⁹ Ibid.

⁹⁰ Gentry, J. January 20, 1989. Handwritten letter to LADEQ, Re: Questions and Comments on Permit Application.

⁹¹ Arcadian. April 21, 1989. "National Survey on Solid Wastes from Mineral Processing Facilities."

⁹² U.S. Environmental Protection Agency, Region 6. May 11, 1989. Letter from K.G. Huffman to M. Harbourt, of Kean et al, Attorneys at Law, Re: Arcadian Corporation, NPDES Permit No. LA0066257.

⁹³ Arcadian. January 15, 1989. Letter from J.J. Baker to T. Hardy, OSHW LADEQ, Re: ID #GD-005-1822 Ground Water Monitoring Report.

limitations are modified, there are no other environmentally acceptable alternatives to the emergency bypass of the clearwell water.⁹⁴ The accumulation of facts throughout the documents suggests that excess water can cause failure of the gypsum stack or of the clearwell walls. During a discharge on February 27, 1987, Arcadian stated that the action was necessary "to prevent possible injury and severe property damage."⁹⁵ Such a discharge occurred again beginning on March 10 of the same year.⁹⁶ During these discharges, pH values ranged from 1.3 to 2.5; phosphorus concentrations from 3,688 mg/L to 7,960 mg/L; and fluorine concentrations from 6,188 to 14,649 mg/L.

An EPA NPDES Violation Summary, based on discharge monitoring reports from March 1986 to December 1987, showed that Outfall 003 violated effluent limits each month from at least December 1985 until August 1987. No enforcement action was taken for any of these violations. Since February of 1987, the EPA inspector has noted: "No action taken - waiting for an enforceable permit." Contaminant concentrations were similar to those listed above.

On December 8, 1988, EPA Region VI issued an Administrative Order to Arcadian regarding several violations, including the discharge on October 28 of that year of calcium sulfate run-off (Outfall 003) containing total phosphorus of 8,176 lbs/day, exceeding the permitted limit of 7,685 lbs/day.⁹⁷

According to the LA DEQ, this facility has not experienced non-compliance or emergency bypass problems since those outlined in this section.

Louisiana -- Other

The management histories described for the above Louisiana facilities are also typical of the other Agrico facilities (Hahnville and Uncle Sam).

12.3.3 Findings Concerning the Hazards of Phosphogypsum and Process Wastewater

Based upon the detailed examination of the inherent characteristics of phosphogypsum and process wastewater arising from the production of wet process phosphoric acid, the management practices that are applied to these wastes, the environmental settings in which the generators of the materials are situated, and the numerous instances of documented environmental damage that have been described above, EPA concludes that current practices are inadequate to protect human health and the environment from the potential danger posed by these wastes.

Intrinsic Hazard of the Wastes

Review of the available data on phosphogypsum and its leachate constituent concentrations indicates that concentrations of 12 constituents exceed one or more of the screening criteria by more than a factor of 10, and that maximum chromium and phosphorus concentrations exceed the screening criteria by factors of greater than 1,000. In addition, two samples of phosphogypsum (out of 28) contained chromium concentrations in excess of the EP toxicity regulatory level, and phosphogypsum frequently contains uranium-238 and its decay products at levels that could present a high radiation hazard if the waste is allowed to be used in an unrestricted manner. This finding leads EPA to conclude that the intrinsic hazard of this waste is moderate to high.

⁹⁴ Kean, et al, Attorneys at Law. November 6, 1984. Letter from M.N. Harbourt to J.V. Ferguson, EPA Region 6, Re: Notice of Anticipated Bypass, NPDES Permit No. LA0066257, Arcadian Corp., EPA File No. 7945-1.

⁹⁵ Arcadian. February 27, 1987. Letter from M.N. Harbourt to J. Van Buskirk, EPA Region 6 and J.D. Givens, LADEQ, Re: Notice of Anticipated Bypass and Request for Order Authorizing Bypass.

⁹⁶ Kean, et al, Attorneys at Law. March 19, 1987. Letter from M.N. Harbourt to J. Von Buskirk, EPA Region 6, Re: Arcadian Corporation - NPDES Permit Number: LA-0066257, EPA File Number: 7945-1.

⁹⁷ U.S. Environmental Protection Agency, Region 6. December 8, 1988. Cover letter from M.O. Knudson to H.J. Baker, Arcadian, Re: Administrative Order Docket No. VI-89-043, NPDES Permit No. LA0066257. 12/8/88. (Administrative Order attached).

Review of the available data on phosphoric acid process wastewater constituent concentrations indicates that phosphorus and phosphate are present at concentrations that sometimes are more than 100,000 times the screening criteria, arsenic and phenol are present at concentrations more than 1,000 times the screening criteria, and 15 additional constituents exceed a screening criteria by a factor of at least 10. In addition, process wastewater exhibits the RCRA hazardous waste characteristics of corrosivity (i.e., pH < 2) and exhibits the characteristic of EP toxicity (based on cadmium, chromium, and selenium concentrations). The wastewater also contains radium-226, gross alpha radiation, and gross beta radiation levels that could pose an unacceptably high radiation hazard if the wastewater is mismanaged. Based on these findings, EPA concludes that the intrinsic hazard of phosphoric acid process wastewater is high.

Potential and Documented Danger

The documented cases of dangers to human health and the environment indicate that phosphogypsum and process wastewater constituents have been released to ground water at a number of facilities and, at some sites, have migrated off-site to potable drinking water wells in concentrations that are well above hazard criteria. Based on the analysis of the damage case evidence, EPA concludes that management of phosphogypsum and process wastewater in stacks and ponds can release contaminants to the subsurface. Given the hydrogeologic setting and ground-water use patterns in the vicinity of most phosphoric acid plants, released contaminants threaten human health via potential drinking water exposures and render ground-water resources unsuitable for potential use.

Based on the analysis of the damage case evidence, it is clear that management of phosphogypsum and process wastewater in stacks and ponds can and does release contaminants to nearby surface waters. Given this evidence of releases, the proximity of most phosphoric acid plants to surface water bodies, and surface water use patterns, EPA concludes that at many phosphoric acid plants these released contaminants migrate to rivers and bays and threaten human health via drinking water exposures, threaten aquatic life, or render surface water resources unsuitable for potential consumptive uses.

EPA risk estimates demonstrate that phosphogypsum stacks pose a considerable air pathway cancer risk as a result of radon emissions from the stacks, with minor contributions from radioactive and nonradioactive constituents in windblown phosphogypsum. EPA estimates a maximum total air pathway lifetime cancer risk for a maximally exposed individual of approximately 9×10^{-5} . This risk is primarily from inhalation of radon emitted from stacks (9×10^{-5}), with minor contributions from the inhalation of windblown phosphogypsum particles containing radionuclides (2×10^{-6}) and arsenic and chromium (7×10^{-7}).

12.4 Existing Federal and State Waste Management Controls

12.4.1 Federal Regulation

Section 3001(b)(3)(B)(iii) of RCRA provides the EPA Administrator with explicit authority to regulate the use of the use of solid wastes from phosphate rock processing for construction or land reclamation so as to prevent radiation exposure which presents an unreasonable risk to human health. EPA has not availed itself of this authority to date, but plans to consider regulatory options under this provision of RCRA to limit the off-site use in construction of elemental phosphorus slag, another special waste from mineral processing (see Chapter 7).

Off-site use of phosphogypsum has already been prohibited by the final National Emission Standards for Hazardous Air Pollutants (NESHAP) for radionuclides that was promulgated on December 15, 1989 (54 FR 51654). This rule requires that as of the effective date of the rule (March 15, 1990), phosphogypsum be disposed in stacks or in mined-out areas, effectively prohibiting use as a construction material or agricultural soil supplement.⁹⁸

⁹⁸On April 10, 1990 EPA published a Notice of Limited Reconsideration that provided a limited class waiver that allows continued use of phosphogypsum for agricultural uses for the duration of the current growing season, but not to extend beyond October 1, 1990. This notice also solicited comment on alternative uses of phosphogypsum, i.e., management practices other than disposal.

Under the Clean Water Act, EPA has the responsibility for setting "effluent limitations," based on the performance capability of treatment technologies. These "technology based limitations," which provide the basis for the minimum requirements of NPDES permits, must be established for various classes of industrial discharges, including a number of mineral processing categories.

Permits for mineral processing facilities may require compliance with effluent guidelines based on best practicable control technology currently available (BPT) or best available technology economically achievable (BAT). BPT effluent limitations of process wastewater from wet-process phosphoric acid, normal superphosphoric acid, and triple superphosphoric acid include (40 CFR 418.12(c)):

Pollutant	Daily Maximum	Monthly Average
Total Phosphorus	105 mg/L	35 mg/L
Fluoride	75 mg/L	25 mg/L
Total Suspended Solids	150 mg/L	50 mg/L

Effluent limitations concerning the concentrations of pollutants contained in (1) the discharge of contaminated non-process wastewater after application of BPT and BAT (40 CFR 418.12(d) and 418.13(d)), (2) discharges of process wastewater related to phosphoric acid production from existing sources after application of BAT (40 CFR 418.13(c)), and (3) process wastewater from defluorination of phosphoric acid after application of BPT and BAT are identical and as follows (40 CFR 422.52(c) and 422.53(c)).⁹⁹

Pollutant	Daily Maximum	Monthly Average
Total Phosphorus	105 mg/L	35 mg/L
Fluoride	75 mg/L	25 mg/L

No discharges of process wastewaters from the production of phosphoric acid or from the defluorination of phosphoric acid are allowed from new sources.

In cases where the State does not have an approved NPDES program, such as Texas, Louisiana, and Florida, EPA Regional personnel have stated that EPA applies the above guidelines. However, EPA may also adopt State water quality standards for the management of these discharges, if applicable. In Idaho, which also does not have an approved NPDES program, the Federal guidelines listed above would apply. EPA Regional staff have not been available to confirm current policy regarding discharges from phosphoric acid facilities. The State of Florida does not currently have an EPA-approved NPDES program. Therefore, existing Federal regulations concerning the management of wastes from the production of phosphoric acid, would apply for facilities in this State. Wastes from phosphoric acid production are subject to the effluent limitation guidelines set forth in 40 CFR Part 418 Subpart A.

The Chevron Chemical Company phosphoric acid facility located in Rock Springs, Wyoming is situated on federal lands managed by the Bureau of Land Management (BLM). The Federal Land Policy and Management Act of 1976 (FLPMA, 43 USC 1732, 1733, and 1782) authorizes BLM to regulate mining activities on its lands with respect to the environmental effects of such activities. BLM regulations implementing this law (43 CFR 3809) are intended to prevent unnecessary or undue degradation of its lands, or lands that are under consideration for inclusion in the national wilderness system. These regulations provide for reclamation of lands disturbed by mining, hence, are not directly applicable to mineral processing activities.

⁹⁹ The limitations for defluorination process wastewater also include daily maximum limits of 150 mg/L and 6-9 and monthly average limits of 50 mg/L and 6-9 for TSS and pH respectively.

12.4.2 State Regulation

The 21 facilities in the phosphoric acid sector are located in seven states, including Florida, Louisiana, Idaho, Mississippi, North Carolina, Texas, and Wyoming. All of these states except Wyoming were selected for regulatory review (see Chapter 2 for a discussion of the methodology used to select states for regulatory study). The majority of the 21 phosphoric acid facilities are located in Florida, Louisiana, and Idaho, which have twelve, three, and two facilities, respectively. Based on the distribution of facilities, therefore, state-level regulation of phosphoric acid processing wastes is of particular interest in the States of Florida, Louisiana, and Idaho.

As a general overview, six of the seven states with phosphoric acid processing facilities (all but Wyoming), adopt the federal exclusion from hazardous waste regulation for special wastes from mineral processing. Florida regulates wastes from the production of phosphoric acid under its solid waste rules, while Louisiana and Texas classify and manage such wastes as industrial solid waste. Mississippi and North Carolina exempt wastes generated in all types of mineral processing facilities from regulation as solid wastes. No requirements in Idaho's solid waste regulations apply to these wastes. Finally, three of seven states (North Carolina, Mississippi, and Wyoming) have EPA-approved NPDES programs while all seven states have air quality control regulations or standards that may be applicable to wastes from mineral processing facilities.

As noted above, most of the phosphoric acid processing facilities under study are located in Florida. Also as noted, Florida adopts the federal exclusion from hazardous waste regulation for mineral processing wastes. The state addresses phosphoric acid processing wastes under its solid waste regulations, though these regulations do not contain requirements pertaining specifically to phosphogypsum stacks or process wastewater cooling ponds. The state issues two types of permits for solid waste disposal activities at phosphoric acid facilities, including an industrial wastewater discharge permit (required for cooling ponds and maintained for some old stacks), and a solid waste disposal permit required of new stacks. Recent monitoring efforts have prompted the state to establish additional controls over stacks. Florida now requires that all discharges to ground water, in addition to established zones of discharge, be addressed by an appropriate permit. The state also applies modified landfill requirements, interim requirements, and limited wastewater facilities regulations, and is in the process of modifying the solid waste regulations with regard to design and operating standards, closure requirements, and financial responsibility requirements applicable to phosphogypsum stacks and cooling ponds.

Current regulation of phosphoric acid processing wastes in Florida, therefore, consists primarily of the requirement to obtain a permit for discharges to ground water and the requirement that new stacks and expansions of existing stacks be clay-lined and undergo formal closure. Under this policy, closure requirements include cover adequate to prevent infiltration and run-off controls. Further, all cooling ponds in the state must have run-on/run-off controls. The state also may place waste disposal location restrictions, performance standards, and operating requirements on a facility's solid waste disposal permit. The Florida Department of Environmental Regulation has the authority to conduct on-site inspections, issue administrative and consent orders, and require remedial action, though it does not have the authority to fine facilities for non-compliance. Finally, although air emissions from the phosphate industry are regulated under the state's air pollution rules, state officials indicated that phosphogypsum stacks typically crust over or are managed as part of a wet system so that fugitive dust emissions traditionally have not been considered a problem.

Louisiana, with three phosphoric acid processing facilities, also excludes mineral processing wastes from regulation as hazardous waste. Louisiana classifies and regulates mineral processing wastes as industrial solid wastes. Although no requirements have been drafted specifically for phosphogypsum stacks, facility owners/operators must comply with provisions for soils (e.g., stability, permeability), hydrologic characteristics, precipitation run-on and run-off, location standards, security, safety, and waste characterization. New stacks must have liners as well. During closure, the owner/operator must emplace a final cover or some alternate erosion control measure. Similarly, process wastewater cooling ponds must meet industrial waste surface impoundment requirements such as run-on controls, liner requirements, design standards (e.g., to prevent overtopping and minimize erosion), and waste characterization and ground-water monitoring requirements. Surface impoundments must be dewatered and clean-closed (i.e., all residuals removed) or closed according to solid waste landfill closure provisions. Owners/operators of both phosphogypsum stacks and process wastewater ponds must maintain financial responsibility for the closure and post-closure care of those units. In addition to these solid waste regulations, the three facilities in Louisiana must comply with federal NPDES permits and

Louisiana Air Emissions Permits. Under the air permits, the facilities must be operated in a manner to minimize fugitive dust and could be required to undertake fugitive dust controls, such as the application of chemicals, asphalt, or water, if deemed necessary by the state. Finally, the state requires that owners/operators obtain a permit in order to construct a new facility or make a major modification to an existing facility.

Like Florida and Louisiana, Idaho, with two phosphoric acid processing facilities, excludes mineral processing wastes from its hazardous waste regulations. Unlike all of the other states with phosphoric acid processing facilities, however, Idaho does not apply any solid waste regulatory requirements to either phosphogypsum stacks or process wastewater cooling ponds. Moreover, the state does not have an approved NPDES program and, although the two facilities located in Idaho are broadly responsible for reasonable control of fugitive dust emissions, the state does not specifically address stacks or ponds in the facilities' air permits.

As noted, Mississippi, North Carolina, and Texas each have a single phosphoric acid facility and exclude those facilities from hazardous waste regulations. The facility located in Mississippi, which is not currently in operation, does have a current Mississippi NPDES permit. Because this facility disposes of its waste on site, however, the state does not require that the owner/operator obtain a solid waste management permit and does not plan to address the phosphoric acid wastes unless a threat to public health and the environment is demonstrated. The facility in North Carolina has a current North Carolina NPDES permit for its wastewaters. In accordance with a state-issued mining permit, the facility currently uses its phosphogypsum as fill for mined-out areas. The state does not regulate the stacks as solid wastes, but rather addresses them with non-discharge permits issued by the Water Quality Section of the Division of Environmental Management. North Carolina has initiated several consent agreements with the facility to address releases to surface and ground waters. The state also recently promulgated new air regulations that address radionuclide contaminants and may result in increased fugitive dust emission controls for phosphogypsum stacks. As with Mississippi, the facility in Texas has not been required to obtain a solid waste permit because it disposes of its wastes on property owned by the facility owner/operator. The facility has notified the state of its waste management activities, however, and has obtained federal NPDES and Texas wastewater discharge permits. Both North Carolina and Texas have addressed air emissions from phosphogypsum stacks only under general emission requirements. The final state with a phosphoric acid processing facility, Wyoming, was not studied in detail for this report. Wyoming appears to regulate its single facility under solid waste regulations and the state's approved NPDES program.

In summary, the two states with the most phosphoric acid processing facilities, Florida and Louisiana, appear to regulate those facilities most comprehensively. Of the remaining states, Mississippi, Texas, and Wyoming have placed fewer regulatory requirements on the phosphoric acid processing wastes managed within their borders, while Idaho has imposed essentially no requirements on the two facilities located within the state. In all cases, the wastes are addressed in general by NPDES, air, and solid waste landfill and surface impoundment requirements only, and not by regulations tailored specifically to phosphogypsum stacks or process wastewater cooling ponds.

12.5 Waste Management Alternatives and Potential Utilization

12.5.1 Waste Management Alternatives

Waste management alternatives, as discussed below, include alternative processes for manufacturing phosphoric acid and methods of purifying (i.e., reducing concentrations of radionuclides and/or other contaminants) the phosphogypsum so that it can be safely used in agriculture or construction. Direct recycling of phosphogypsum is not a viable alternative, because the phosphogypsum itself cannot be used in the production of phosphoric acid, although it is already common practice to recycle the process water used to slurry the phosphogypsum. One exception to this, as is discussed briefly in the section on utilization, is the production of sulfur dioxide (SO₂) by the thermal decomposition of phosphogypsum, which can be recycled to the manufacturing process as sulfuric acid.

Process Alternatives for Manufacturing Phosphoric Acid

There are a number of variations of the basic wet-acid process used to manufacture phosphoric acid. These alternative processes are considered in this section because the phosphogypsum that they generate may differ in its degree of hydration (hemihydrate vs. dihydrate) at the time of generation, which can determine which purification methods can be applied to the phosphogypsum, and how efficiently they can remove the impurities. In addition, the amount of preprocessing required before some types of utilization (e.g., as wall board or plaster) can also vary with the production process used. Unfortunately, there is insufficient data available to attempt an evaluation the volume, composition, or potential hazard(s) of the phosphogypsum generated by the different processes. Consequently, this discussion focuses on the differences that could be relevant to the subsequent treatment, utilization, or disposal of phosphogypsum generated by the different production processes.

Description

The processes to be discussed are the classic Prayon and Nissan-H processes which generate the dihydrate form of phosphogypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$); and the Central-Prayon and Nissan-C processes, which generate the hemihydrate form of phosphogypsum ($\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$).

In the classic Prayon process, the dihydrate phosphogypsum is filtered out of the solution produced by the digestion of phosphate rock by sulfuric acid. The phosphogypsum is then pumped as a slurry to gypsum stacks for disposal.^{100,101}

In the Central-Prayon process, the dihydrate phosphogypsum is filtered out of the solution produced by the digestion of phosphate rock by sulfuric acid. The phosphogypsum is converted to the hemihydrate form by heating it and adding sulfuric acid, whereupon the hemihydrate/phosphogypsum is extracted from the acid slurry by counter-current washing, and the liquid is recycled to the phosphate rock digestion process, and the hemihydrate slurry being sent to the stacks for disposal.¹⁰²

In the Nissan-H process, the phosphate rock is digested by sulfuric acid at a high temperature which causes most of the phosphate rock to decompose and the hemihydrate form of phosphogypsum to be generated.¹⁰³ The hemihydrate slurry is cooled and recrystallized to dihydrate by using seed crystals of dihydrate phosphogypsum. This recrystallization step results in the formation of phosphogypsum crystals which can be easily filtered, and are believed to be of sufficient quality to be utilized in building materials without additional treatment.^{104,105}

The Nissan-C process is very similar to the Nissan-H process, the main difference being that the hemihydrate slurry is recrystallized by both cooling it and changing its acid concentration, which results in phosphoric acid concentrations of 45-50 percent without evaporation (as opposed to the 30-35 percent normally produced by the dihydrate processes) and in a higher quality phosphogypsum.¹⁰⁶

Current and Potential Use

It is uncertain which of the above processes are used by each of the phosphoric acid facilities, although EPA believes that at least two or three of the facilities use one of the processes (Central-Prayon or Nissan-C) which generate

¹⁰⁰ Pena, N., Utilization of the Phosphogypsum Produced in the Fertilizer Industry, UNIDO/IS.533, United Nations Industrial Development Organization (UNIDO), May 1985, p. 30.

¹⁰¹ Muehlberg, P.E., J.T. Reding, B.P. Shepherd, Terry Parsons and Glynda E. Wilkins, Industrial Process Profiles for Environmental Use: Chapter 22. The Phosphate Rock and Basic Fertilizer Materials Industry, EPA-600/2-77-023v, Environmental Protection Technology Series, prepared for Industrial Environmental Research Laboratory, ORD, U.S. Environmental Protection Agency, February 1977, p. 21.

¹⁰² Ibid., p. 31.

¹⁰³ Ibid., p. 14.

¹⁰⁴ Ibid., p. 16.

¹⁰⁵ The absence of supporting data has prevented EPA from evaluating the validity of this statement.

¹⁰⁶ Muehlberg, op. cit., p. 18.

hemihydrate phosphogypsum, and that the rest of the facilities use one of the processes (classic Prayon or Nissan-H) which generate dihydrate phosphogypsum.

There do not appear to be any insurmountable obstacles preventing any of the facilities from using any of the available production processes. Some of the reasons why particular facilities use, or have converted to, a particular process have been that the hemihydrate processes are more energy efficient because the phosphoric acid that they produce is more concentrated (hence, requires less evaporative concentration, which is energy-intensive), and that the dihydrate processes are easier to control and maintain. If it becomes necessary to reduce the radionuclide content in the phosphogypsum (see the discussion of phosphogypsum purification below) so that it could be utilized rather than disposed (see section 12.5.2), facilities might have more incentive to begin using one of the processes which generate hemihydrate phosphogypsum, since the two purification methods which employ acid digestion require anhydrite or hemihydrate phosphogypsum.

Purification of Phosphogypsum

Utilization of phosphogypsum in construction and agriculture is constrained by the presence of impurities and hazardous constituents in the waste. Constituents such as radium-226 and arsenic may need to be removed because of the hazards they may present to human health and the environment, while phosphates and fluorides need to be removed for technical reasons related to the methods of utilization. The impurities include insolubles such as silica sand and unreacted phosphate ore; occluded water soluble phosphoric acid and complex fluoride salts; and interstitially trapped ions within the phosphogypsum crystal lattice, such as HPO_4^{2-} , AlF_5^{2-} , and radioactive radium-226.¹⁰⁷

Description

Several processes for removing radium-226, as well as the other impurities, have recently been developed.^{108,109} These processes involve either acid digestion of the phosphogypsum or simple physical removal of the more radioactive portions of the phosphogypsum.

The method of physical separation can reduce the radionuclide concentration of the phosphogypsum by approximately 30 percent. The method involves the use of a hydrocyclone to remove the phosphogypsum crystals smaller than 30 microns (which contain the greatest proportion of radionuclides) from the bulk of the phosphogypsum.¹¹⁰

While the two acid digestion processes are more complicated and costly, they can remove nearly all of the radioactive constituents. The acid digestion processes are similar to one another; the primary difference between the processes is whether anhydrite (CaSO_4) or hemihydrate ($\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$) is used as a reaction intermediate in the purification sequence. Both processes can be applied to dihydrate phosphogypsum, although it must first be dehydrated with sulfuric acid.

During the anhydrite purification method, phosphogypsum is placed in concentrated sulfuric acid where it is dehydrated and reprecipitated as small anhydrite crystals. Most of the soluble ions are removed from the phosphogypsum, while the radium-226 is precipitated with the anhydrite. (Silica sand also remains with the solid anhydrite.) The anhydrite is rehydrated with a dilute solution of sulfuric acid at a temperature less than 43°C, and gypsum seed crystals are used to speed up the rate of hydration. The remaining anhydrite crystals, along with the radium-226, can be readily separated from the larger gypsum crystals, although some of the very small anhydrite crystals adhere to the surface of the gypsum crystals, which increases the radionuclide content of the purified phosphogypsum.

¹⁰⁷ Palmer, J.W., and J.C. Gaynor, Phosphogypsum Purification, USG Corporation, Libertyville, Illinois, May 30, 1985, p. 1.

¹⁰⁸ Ibid.

¹⁰⁹ Palmer, J.W., Process for Reducing Radioactive Contamination in Phosphogypsum, U.S. Patent 4,338,292 to USG Corporation, June 14, 1983, p. 2.

¹¹⁰ Pena, N., Utilization of the Phosphogypsum Produced in the Fertilizer Industry, UNIDO/IS.533, United Nations Industrial Development Organization (UNIDO), May 1985, p. 32

During the hemihydrate purification method, the hemihydrate slurry is cooled, purified gypsum seed crystals are added, and large crystals of purified phosphogypsum are produced. Most of the radionuclides remain in the hemihydrate crystals, and the large dihydrate phosphogypsum crystals are easily separated from the smaller hemihydrate crystals.

The dilute sulfuric acid, used to rehydrate the anhydrite or hemihydrate, contains phosphate value from the phosphogypsum that can be recovered at the phosphoric acid plant. Silica sand is removed from the slurry by hydraulic classification.

An approximately 99.5 percent pure phosphogypsum can be obtained using either of these two processes. The hemihydrate route gives a 1 pCi/g radiation level, while the anhydrite route gives a 3 pCi/g level. Natural gypsum typically contains 1 to 3 pCi/g radiation.

Current and Potential Use

In the literature reviewed by EPA, no evidence was found to indicate that any of the phosphoric acid facilities are currently purifying their phosphogypsum. Future use of the purification methods will primarily depend on how the regulations constrain the disposal and utilization of phosphogypsum (see section 12.5.2).

Of the three purification methods described above, the physical separation process has only limited potential use. Since the physical separation process will only remove 30 percent of the radium-226, the use of this process is limited to phosphogypsum containing 14 pCi/g or less of radium-226 (i.e., a 30 percent reduction from 14 pCi/g will yield 9.8 pCi/g). This is assuming that phosphogypsum with a radium-226 content of greater than 10 pCi/g could not be utilized (see 54 FR 13482, April 10, 1990).

Exhibits 12-7 and 12-8 summarize phosphogypsum radium-226 content on a regional and facility-specific basis. Facility-specific information was available for only 7 of the 21 phosphoric acid production facilities. It should be noted that phosphate ores processed in Louisiana, Mississippi, and Texas originate from Florida. The radium-226 content of the North Carolina phosphogypsum falls below the tentative threshold level of 10 pCi/g radium-226 and, therefore, would not require purification. Phosphogypsum generated in Florida, Idaho, Louisiana, and Mississippi have radium-226 concentration ranges too high for the physical separation process to purify more than a fraction of the phosphogypsum to a level below the threshold level. However, the phosphogypsum generated in Texas has a low enough radium-226 concentration that the method

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of physical separation should be able to reduce the radium-226 concentration below the 10 pCi/g threshold in most of the phosphogypsum generated.

Therefore, it appears that only a small portion of phosphogypsum produced annually could be sufficiently purified by the physical separation technique. In order to reduce all the phosphogypsum to a level at or below the 10 pCi/g threshold, the purification methods using acid digestion would be required.

Factors Affecting Regulatory Status

The residuals generated by the acid digestion purification of phosphogypsum have a specific activity of up to 600 pCi/g¹¹¹, and while the purification process generates a relatively low volume of waste, it is very concentrated and may pose disposal problems that equal or outweigh those associated with the original phosphogypsum. At this time, however, EPA does not have sufficient information to articulate a position on the regulatory status of this residue. One waste management strategy which has been suggested for immobilizing the radionuclides is to blend it with waste phosphatic clay suspensions (slimes) and allow the mixture to solidify.¹¹² The discussion in Section 12.5.2 on utilization of phosphogypsum in mine reclamation provides an explanation of this approach.

While no information was found on the volume or radium-226 concentration of the waste resulting from the physical separation method, it too would produce residuals with relatively high concentrations of radium-226.

12.5.2 Utilization

Described below are a number of alternatives for utilizing phosphogypsum. Some of these uses, such as agriculture and mine reclamation, already utilize significant amounts of phosphogypsum. Other alternatives (e.g., use as a construction material) have been shown to be technically feasible, but for a variety of reasons have not moved beyond the developmental stage of field testing in the U.S.

At the time of this assessment, it is uncertain which, if any, of the uses discussed below will be allowed. EPA currently requires that phosphogypsum be disposed in stacks or mines, which precludes alternative uses of the material,¹¹³ except for a limited class waiver for the agricultural use of phosphogypsum, which will be in effect until October 1, 1990. EPA has, however, announced a limited reconsideration of the rule requiring the disposal of phosphogypsum in stacks or mines, and has also given notice of a "proposed rulemaking by which EPA is proposing to maintain or modify the rule to, alternatively or in combination, (1) make no change to 40 CFR Part 61, subpart R, as promulgated on October 31, 1989, (2) establish a threshold level of radium-226 which would further define the term "phosphogypsum", (3) allow, with prior EPA approval, the use of discrete quantities of phosphogypsum for researching and developing processes to remove radium-226 from phosphogypsum to the extent such use is at least as protective of public health as is disposal of phosphogypsum in mines or stacks, or (4) allow, with prior EPA approval, other alternative use of phosphogypsum to the extent such use is at least as protective of public health as is disposal of phosphogypsum in mines or stacks."¹¹⁴

¹¹¹ Moisset, J., Location of Radium in Phosphogypsum and Improved Process for Removal of Radium from Phosphogypsum, Platres Lafarge (France) (date not known).

¹¹² Palmer, J.W. and J.C. Gaynor, Method for Solidifying Waste Slime Suspensions, U.S. Patent 4,457,781 to USG Corporation, July 3, 1984, p. 4.

¹¹³ 54 FR 51654, December 15, 1989.

¹¹⁴ 55 FR 13482, April 10, 1990.

With respect to these four regulatory options, this report does not discuss options (1) or (3), other than to say that option (1) would preclude all of the alternative uses, with the possible exception of mine reclamation, and that it is unlikely that the option (3) would result in a significant reduction in the amount of phosphogypsum requiring disposal in mines or stacks.

Utilization of Phosphogypsum in Agriculture

Description

Phosphogypsum has been used in agriculture as a source of calcium and sulfur for soils that are deficient in these elements. Phosphogypsum is also incorporated into soils in order to provide sediment control for soils that have been eroded and leached to the point where they have developed a compacted crust. In addition, phosphogypsum is sometimes incorporated into acidic soils to serve as a buffering agent.

Phosphogypsum is sometimes pelletized before being applied to the soil, though the majority of phosphogypsum used for agricultural purposes is taken directly from disposal stacks, transported to local fertilizer companies, and distributed to the farmers. When the phosphogypsum is used as a fertilizer it is simply spread on the top of the soil, whereas when it is used for pH adjustment or sediment control it is tilled into the soil.

Current And Potential Use

It is estimated that 1,260,000 metric tons of gypsum are used in agriculture each year.¹¹⁵ Of this amount, approximately 221,000 metric tons is from phosphogypsum stacks, 318,000 metric tons is from by-product gypsum processors, and 721,000 metric tons is from natural gypsum mines and quarries.¹¹⁶

As discussed above, EPA currently requires that phosphogypsum be disposed in stacks or mines, although a limited class waiver for agricultural use of phosphogypsum is in effect until October 1, 1990. After October 1, 1990, agricultural uses of phosphogypsum will not be allowed unless EPA decides to implement regulatory options (2) or (4) identified above.

If a threshold level of radium-226 is established (regulatory option (2)), it may be possible to utilize the phosphogypsum after purification (i.e., reducing the radium-226 content) (see section 12.5.1). If the physical separation method described in section 12.5.1 were used to purify phosphogypsum, the data displayed in Exhibits 12-7 and 12-8 suggest that some of the phosphogypsum generated in the states of Florida, Idaho, Louisiana, Mississippi, North Carolina, and Texas might have a radium-226 content below the threshold level of 10 pCi/g. However, the available data are not detailed enough for EPA to estimate how much of the purified phosphogypsum at each facility would fall below the threshold level. If either of the acid digestion purification methods (see section 12.5.1) were used to purify the phosphogypsum, the data in Exhibits 12-8 and 12-9 suggest that all of the phosphogypsum generated in the U.S. would have radium-226 concentrations below the threshold level.

Factors Relevant to Regulatory Status

A 1978 radiological assessment of the application of phosphogypsum to vegetable crop land concluded that there is little reason for concern regarding potential radiological hazards from the uptake of radium-226 by vegetable plants grown in soils treated with phosphogypsum.

In a different study, data on the radium-226 content of phosphogypsum samples from Florida and Idaho were used to calculate the increase in radium-226 content of soil to which phosphogypsum is applied. The study found that

¹¹⁵ McElroy, Christopher J., Petition of United States Gypsum Company for Partial Reconsideration and Clarification, and Opposition of United States Gypsum Company to the Petition for Partial Reconsideration and Request for Stay of the Fertilizer Institute, United States Gypsum Company, February 9, 1990.

¹¹⁶ Ibid.

the application of 1 metric tons of 40 pCi/g phosphogypsum to 1 hectare of land, and mixed in the soil to a depth of 20 cm, would increase the radium-226 content of the soil by 0.01538 pCi/g. Therefore, the application of phosphogypsum for the purpose of sulfur fertilization (assuming an application rate of 0.1 metric tons per hectare per year) would result in an increase in the soil's radium-226 content of 0.0015 pCi/g-year, while the application of phosphogypsum for the purpose of sediment control (assuming an application rate of 4.0 metric tons per hectare per year) would result in an increase in the soil's radium-226 content of 0.62 pCi/g-year. Over a period of 100 years, these application rates would cause radium-226 concentrations to increase by 0.15 and 6.2 pCi/g, respectively, as compared to the typical radium-226 content in soils of 1-2 pCi/g.¹¹⁷

Feasibility

It is uncertain whether future regulations will completely preclude the agricultural uses of phosphogypsum, or only limit when and how it may be used.¹¹⁸ Since many farmers have continued to use phosphogypsum despite the prospect of new regulatory prohibitions, and concerns about the radium-226 found in phosphogypsum,¹¹⁹ it is not unreasonable to assume that farmers would continue to use it in the future, if it remains economically competitive. However, if it becomes necessary to reduce the radium-226 content before it can be used, the additional costs are likely to reduce the amount of phosphogypsum used if purification would make phosphogypsum more expensive than the materials it competes with.

Utilization of Phosphogypsum for Mine Reclamation

Description

An alternative to the direct disposal of phosphogypsum in stacks and/or mines has been developed in which phosphogypsum is mixed with phosphatic clay suspension (a waste stream from the beneficiation of phosphate rock), and placed in a disposal site (generally the phosphate mine) where it consolidates and can be reclaimed by planting grass and trees.¹²⁰ The process begins by increasing the solids content of the phosphatic clay suspension to 10 percent; a portion of the dewatered clay is pumped to the phosphoric acid plant and mixed with phosphogypsum from the belt-filters; the clay-phosphogypsum mixture (blend) is put into a blend tank and additional phosphogypsum from the stacks and phosphatic clay suspension are added until there are approximately 3 parts phosphogypsum to 1 part clay; the resulting blend (35 percent solids) is pumped as a slurry to the disposal site; and after the blend has had approximately one year to dewater and consolidate, it is possible to plant grass and trees on the surface.¹²¹

Current and Potential Use

Only Texasgulf's facility in Aurora, North Carolina is known to be using this management practice. To date, Texasgulf has used the phosphogypsum-clay blend to reclaim a 400 acre¹²² portion of a phosphate mine adjacent to the facility, and is currently utilizing phosphogypsum at about the same rate as it is being generated.¹²³

In considering whether any of the other 18 facilities could utilize their phosphogypsum in this way, there are at least two factors which need to be considered. The first factor is that the phosphoric acid plant be located near

¹¹⁷ Bureau, R.G., Agricultural Impact of Radium-226 in Gypsum Derived from Phosphate Fertilizer Manufacture, October 1976.

¹¹⁸ 55 FR 13482 April 10, 1990.

¹¹⁹ Personal communication, Dr. Gary Gascho, University of Georgia Experiment Station, April 25, 1990.

¹²⁰ Palmer, Jay W. and A.P. Kouloheris, Slimes Waste Solidification with Hydratable Calcium Sulfate, paper to be presented at the University of Miami Civil Engineering Department Seminar on Phosphogypsum on April 25-27, 1984, p. 279.

¹²¹ Personal communication, William A. Schimming, Environmental Affairs Manager, Texasgulf Inc., April 30, 1990.

¹²² The filled area was approximately 35 feet deep.

¹²³ Schimming, *op. cit.*

enough to the disposal site to keep transportation costs to a minimum. The second factor is that the phosphatic clay suspension contain sufficient base (e.g., calcium carbonate) to neutralize the acids in the phosphogypsum. Some of the facilities in Idaho and Florida may be close enough to their mines to utilize their phosphogypsum (total of 45,777,691 metric tons in 1988)¹²⁴ for mine reclamation, although this is not at all certain. The facilities in Louisiana, Mississippi, and Texas could not use this option to utilize their phosphogypsum (8,911,000 metric tons in 1988)¹²⁵ because their phosphate rock is mined in central Florida, nor could the Chevron Chemical facility in Rock Springs, Wyoming (836,000 metric tons phosphogypsum in 1988),¹²⁶ because its phosphate rock is mined in Utah. EPA does not know whether any of the phosphatic clay suspensions generated outside of North Carolina are sufficiently basic to neutralize the acids in the phosphogypsum.

Factors Relevant to Regulatory Status

EPA believes that the utilization of phosphogypsum to reclaim mines may have a number of advantages over the current practice of placing it in stacks or mines. Specifically, having grass and trees growing over the reclaimed mine will reduce the potential for the waste to be released to surface water by erosion, or to the atmosphere as wind blown dust. It should also reduce the demand for surface impoundments needed for the disposal of phosphatic clay suspension. Finally, the reclaimed disposal sites will be more aesthetically pleasing than the stacks and mines currently used to dispose phosphogypsum. While there are no obvious disadvantages, contaminant releases from areas reclaimed in this manner, particularly to ground water is a potential problem. EPA has not found any information regarding the migration of hazardous constituents from the phosphogypsum-clay blend into ground or surface waters.

The radiological and chemical composition of the phosphogypsum-clay blend will vary widely, due to differences in phosphate ore and manufacturing processes. Texasgulf believes that its phosphogypsum-clay blend has approximately the same radionuclide concentrations as the original phosphogypsum.¹²⁷ This belief is consistent with data from central Florida in which the concentration of radium-226 is 23.8 pCi/g in phosphatic clay suspensions, and 25.9 pCi/g in the phosphogypsum.¹²⁸ While not much data on the chemical, radiological, or physical characteristics of the phosphogypsum-clay blend is currently available, North Carolina State University's, Department of Soil Science is reportedly in the process of investigating these issues.¹²⁹

Feasibility

It is likely that this management alternative will have a greater level of social acceptability than current practices, which result in large, barren disposal areas. EPA does not believe that the rule requiring that phosphogypsum be disposed in stacks or mines (thereby precluding alternative uses of the material) will preclude the use of this alternative, since it does not involve putting the phosphogypsum-clay blend anywhere except in stacks and mines.¹³⁰ The greatest barriers to the use of this alternative appear to be geographic and technical in nature (see the discussion on Current and Potential Use), although there may also be some economic barriers (e.g., current practices are less expensive).

Utilization of Phosphogypsum in Construction Materials

¹²⁴ Ibid.

¹²⁵ Company responses to EPA's "National Survey of Solid Wastes from Mineral Processing Facilities," conducted in 1989.

¹²⁶ Ibid.

¹²⁷ Schimming, op. cit.

¹²⁸ Palmer, J.W. and A.P. Kouloheris, Slimes Waste Solidification with Hydratable Calcium Sulfate, Paper to have been presented at the University of Miami Civil Engineering Department Seminar on Phosphogypsum, April 25-27, 1984, p. 278.

¹²⁹ Schimming, op. cit.

¹³⁰ 54 FR 51654 December 15, 1989.

Phosphogypsum can be utilized as a construction material in a variety of ways. The two major areas of use are in building materials and highway construction. This section describes and evaluates applications in both areas.

Description

Phosphogypsum has the same basic properties as natural gypsum and may be used as a substitute for natural gypsum in the manufacture of commercial construction products. Approximately 70 percent of the natural gypsum used in the U.S. is for the manufacture of gypsum board or partition panels. Another 19 percent is used as an additive to cement. Addition of natural gypsum to cement retards the setting time, counteracts shrinkage, speeds the development of initial strength, and increases long-term strength and resistance to sulfate etching. The remaining 11 percent of all natural gypsum use is attributable to agricultural uses (7 percent) and miscellaneous uses including the manufacture of plaster and cement.¹³¹ Phosphogypsum generated from the classic Prayon process for phosphoric acid production must be purified by removing phosphates, fluorides, and other impurities for it to be successfully used in the production of building materials or as an additive to cement, whereas phosphogypsum from the Central-Prayon, Nissan-H, and Nissan-C processes may often be used directly as natural gypsum substitutes without the need for purification.

Phosphogypsum from all four processes may often be used in the manufacture of cement without additional purification. One of the most promising processes for utilizing phosphogypsum in the manufacture of portland cement is the OSW-Krupp process, a modification of the Müller-Kühne process. In this process, phosphogypsum is dried in a rotary dryer and mixed with coke, sand, and clay. The mixture is then ground, pelletized, and fed to a rotary kiln where SO_2 and clinker are formed. The SO_2 can then be passed to an acid conversion plant to produce H_2SO_4 , which may be recycled to the phosphoric acid production process. The clinker is cooled and metered along with natural gypsum onto a belt conveyor feeding into a finished cement mill.¹³²

Phosphogypsum generated from all phosphoric acid production processes may be used successfully as a road base, when stabilized with 5-10 percent portland cement or 15-25 percent fly ash, mixed with granular soil and compacted for secondary road construction, used in a portland cement concrete mixture and compacted to form roller-compacted concrete for paving driveways and parking areas, or used as fill and sub-base material.^{133,134}

Current and Potential Uses

Currently, there are no major uses of phosphogypsum in the U.S. in the manufacture of building materials or in highway construction due to the low-cost availability of other suitable materials and to the ban on utilization of phosphogypsum under 40 CFR part 61, subpart R, National Emission Standards for Hazardous Air Pollutants, Radon Emissions from Phosphogypsum Stacks.

The U.S. has led the world in the mining of natural gypsum, with 20 percent of total world output. The cost of purifying and dewatering phosphogypsum and the relative abundance of natural gypsum has historically discouraged the development of phosphogypsum as a replacement for gypsum in the manufacture of building materials in the U.S.¹³⁵ It is unlikely that there will be a significant increase in the utilization of phosphogypsum in this capacity as long as there is a relatively abundant, low-cost supply of natural gypsum in the U.S.

¹³¹ Chang, W.F. and Murray I. Mantell, Engineering Properties and Construction Applications of Phosphogypsum, Phosphate Research Institute, University of Miami Press, Coral Gables, Florida, 1990, p. 6.

¹³² Zellars-Williams Company, A.P. Kouloheris, principal investigator, Evaluation of Potential Commercial Processes for the Production of Sulfuric Acid From Phosphogypsum, Publication No. 01-002-001, Florida Institute of Phosphate Research, October 1981, pp. 18, 22.

¹³³ Ibid., pp. 177-189.

¹³⁴ Collins, R.J. and R.H. Miller, Availability of Mining Wastes and Their Potential for Use as Highway Material - Volume I: Classification and Technical and Environmental Analysis, FHWA-RD-76-106, prepared for Federal Highway Administration, May 1976, p. 146.

¹³⁵ Fitzgerald, J.E., Jr. and Edward L. Sensintaffar, "Radiation Exposure from Construction Materials Utilizing Byproduct Gypsum from Phosphate Mining", (date not known), p. 353.

Utilization of phosphogypsum in the production of H_2SO_4 and cement clinker would be possible in Florida. This application is most feasible where there is a shortage of sulfur and a high demand for cement. Its potential for success in Florida depends upon the sulfur market and the ability of a fertilizer company to market the cement clinker produced.¹³⁶

Phosphogypsum has been successfully used on an experimental basis for paving and highway construction in both Texas and Florida. Phosphogypsum from Mobil's facility in Pasadena was stabilized with fly ash or portland cement and used as a road base on five test sections of city streets in La Porte, Texas.¹³⁷ In Polk County, Florida, the use of phosphogypsum as road base was demonstrated on a 2.4 km (1.5 mile) stretch of road, where it was mixed with granular soil and compacted prior to installation.¹³⁸ Another demonstration of using phosphogypsum as a road base occurred in Columbia County, Florida, where both 100 percent dihydrate phosphogypsum and mixtures of phosphogypsum-sand were used in a 2 mile stretch of road.¹³⁹ Phosphogypsum was also used as a component (13 percent) of roller-compacted concrete, which was used to pave 2,000 square yards of driveways and parking areas at the Florida Institute of Phosphate Research in Bartow, Florida.¹⁴⁰

The actual commercial use of phosphogypsum as a road sub-base material has been demonstrated on a small scale in both Florida and North Carolina. In Florida it was used as sub-base roads at phosphorous processing facilities in central Florida, and as limestone substitute in the road sub-base of a section of blacktop road. In North Carolina it has been used as fill and sub-base in roads crossing swampy areas.¹⁴¹

Factors Affecting Regulatory Status

The primary regulatory concerns with respect to the disposal and utilization of phosphogypsum stem from its radium-226 content. The radium-226 is of sufficient concern that EPA currently requires phosphogypsum to be disposed of in a stack or mine, thereby precluding all of the construction uses discussed above. As is discussed at the beginning of this section, EPA is currently considering a number of regulatory options, two of which could conceivably allow phosphogypsum to be utilized in construction.

If a threshold level of radium-226 is established (regulatory option (2)), it may be possible to utilize the phosphogypsum after purification (i.e., reducing the radium-226 content) (see section 12.5.1). Assuming that the proposed threshold level of 10 pCi/g were adopted, and the physical separation method described in section 12.5.1 were used to purify the phosphogypsum, the data displayed in Exhibits 12-7 and 12-8 suggest that some of the phosphogypsum generated in the states of Florida, Idaho, Louisiana, Mississippi, North Carolina, and Texas might have a radium-226 content lower than the threshold value of 10 pCi/g. However, the available data are not detailed enough for EPA to estimate how much of the purified phosphogypsum would contain less radium-226 than the threshold level, or if phosphogypsum with a sufficiently low radium-226 concentration would be close enough to the potential markets for it to be economically competitive. Similarly, if one of the acid digestion purification methods (see section 12.5.1) were used to purify the phosphogypsum, the data in Exhibits 12-7 and 12-8 suggest that all of the phosphogypsum generated in the U.S. would have radium-226 concentrations lower than the threshold level.

It is not clear whether adoption of the fourth regulatory option would preclude the use of phosphogypsum in construction materials. It is likely that the determination of whether a particular use of phosphogypsum is at least as protective of human health and the environment as phosphogypsum disposal in stacks or mines, would have to be made on a case by case basis.

¹³⁶ Kouloheris, *op. cit.*, p. 16.

¹³⁷ Chang, *op. cit.*, p. 177.

¹³⁸ *Ibid.*, p. 178.

¹³⁹ *Ibid.*, p. 183.

¹⁴⁰ *Ibid.*, pp. 186-187.

¹⁴¹ Collins, *op. cit.* p. 146.

Feasibility

Even if it is allowed by the regulations, it is uncertain whether a significant amount of phosphogypsum would be utilized as a construction material. The basis for this conclusion is that even before the current constraints on the utilization of phosphogypsum were imposed, very little phosphogypsum has been used in construction; consumer concern over indoor radon is likely to discourage the use of products made from phosphogypsum, which may be perceived as a significant source of radon even if purified; natural gypsum is readily available in most parts of the U.S.; and there is concern about the exposure (e.g., via leaching and subsequent ingestion, see section 12.3.1) of humans to the hazardous constituents in phosphogypsum.

12.6 Cost and Economic Impacts

Section 8002(p) of RCRA directs EPA to examine the costs of alternative practices for the management of the special wastes considered in this report. EPA has responded to this requirement by evaluating the operational changes that would be implied by compliance with three different regulatory scenarios, as described in Chapter 2. In reviewing and evaluating the Agency's estimates of the cost and economic impacts associated with these changes, it is important to remember what the regulatory scenarios imply, and what assumptions have been made in conducting the analysis.

The focus of the Subtitle C compliance scenario is on the costs of constructing and operating hazardous waste land disposal units. Other important aspects of the Subtitle C system (e.g., corrective action) have not been explicitly factored into the cost analysis. Therefore, differences between the costs estimated for Subtitle C compliance and those under other scenarios (particularly Subtitle C-Minus) are less than they might be under an alternative set of conditions (e.g., if most affected facilities were not already subject to Subtitle C). The Subtitle C-Minus scenario represents, as discussed above in Chapter 2, the minimum requirements that would apply to any of the special wastes that are ultimately regulated as hazardous wastes; this scenario does not reflect any actual determinations or preliminary judgments concerning the specific requirements that would apply to any such wastes. Further, the Subtitle D-Plus scenario represents one of many possible approaches to a Subtitle D program for mineral processing special wastes, and has been included in this report only for illustrative purposes. The cost estimates provided below for the three scenarios considered in this report must be interpreted accordingly.

In accordance with the spirit of RCRA §8002(p), EPA has focused its analysis on impacts on the firms and facilities generating the special wastes, rather than on net impacts to society in the aggregate. Therefore, the cost analysis has been conducted on an after-tax basis, using a discount rate based on a previously developed estimate of the weighted average cost of capital to U.S. industrial firms (9.49 percent), as discussed in Chapter 2. Waste generation rate estimates (which are directly proportional to costs) for the period of analysis (the present through 1995) have been developed in consultation with the U.S. Bureau of Mines.

In this section, EPA first outlines the way in which it has identified and evaluated the waste management practices that would be employed under different regulatory scenarios by facilities producing wet process phosphoric acid. Next, the section discusses the cost implications of requiring these changes to existing waste management practices. The last part of the section discusses and predicts the ultimate impacts of the increased waste management costs faced by the affected facilities.

12.6.1 Regulatory Scenarios and Required Management Practices

Because the available data indicate that process wastewater and phosphogypsum may exhibit the hazardous waste characteristics of EP toxicity and/or corrosivity, these materials would in many cases be regulated as hazardous wastes under RCRA Subtitle C were it not for the the Mining Waste Exclusion. A decision by EPA that Subtitle C regulation is appropriate for these wastes would therefore result in incremental waste management costs. Accordingly, the Agency has estimated the incidence, magnitude, and impacts of these costs for the facilities that generate process wastewater and phosphogypsum from wet process phosphoric acid production; this analysis is presented in the following paragraphs.

EPA has adopted a conservative approach in conducting its cost analysis for the wastes generated by the phosphoric acid sector. The Agency has assumed that process wastewater would exhibit EP toxicity and corrosivity at all facilities unless actual sampling and analysis data demonstrate otherwise; EPA's waste sampling data, indicate that process wastewater exhibits at least one characteristic of hazardous waste at all facilities from which sampling data are available. Furthermore, because of current co-management of process waters at phosphoric acid facilities, the Agency has assumed that all process wastewaters managed at the facilities have similar chemical characteristics, that is, all circulating process water is assumed to be corrosive and/or EP toxic. In reality, the aggregate process wastewater stream may be separated into different process streams; only those that are potentially hazardous would require treatment. EPA's estimated compliance costs for managing process wastewater may, therefore, be overstated.

Similarly, in following a conservative approach, the Agency has assumed that phosphogypsum would exhibit EP toxicity at all facilities unless actual sampling and analysis data demonstrate otherwise. EPA's waste sampling data indicate that EP toxicity is not exhibited at 10 of facilities that generate the material; the Agency's cost and impact analysis of phosphogypsum management is, therefore, limited to eleven facilities, only one of which was both sampled and at which phosphogypsum constituent concentrations exceed one or more of the EP toxicity regulatory levels.

The Agency has estimated the costs associated with Subtitle C regulation, as well as with two somewhat less stringent regulatory scenarios, referred to here as "Subtitle C-Minus" and "Subtitle D-Plus" (a more detailed description of the cost impact analysis and the development of these regulatory scenarios is presented in Chapter 2, above). In the following paragraphs, EPA discusses the assumed management practices that would occur under each regulatory alternative.

Process Wastewater

Subtitle C

Under Subtitle C standards, hazardous waste that is managed on-site must meet the standards codified at 40 CFR Parts 264 and 265 for hazardous waste treatment, storage, and disposal facilities. The Agency has assumed that the process wastewater and the phosphogypsum can and will be managed separately; non-hazardous process water is assumed to be used to transport the phosphogypsum to the management unit. Because phosphoric acid production process wastewater is a dilute, aqueous liquid, that is usually corrosive and often EP toxic, the management practice of choice under Subtitle C is treatment (neutralization and/or metals precipitation). The scenario examined here involves construction of a Subtitle C surge pond (double-lined surface impoundment) which feeds a system of concrete impoundments in which treatment is performed. Following treatment, the effluent may be reused by the facility (e.g., to slurry fluorogypsum to the gypsum stack or impoundment) just as it is under current practice. The sludge is assumed to be non-hazardous and is assumed to be disposed of in an unlined disposal impoundment or landfill.

Subtitle C-Minus

Assumed practices under Subtitle C-Minus are identical to those described above for the full Subtitle C scenario, with the exception that some of the requirements for construction and operation of the hazardous waste surge pond have been relaxed, most notably the liner design requirements.

Subtitle D-Plus

Assumed practices under Subtitle D-Plus are identical to those described above for the Subtitle C-Minus scenario. Generators of process wastewaters are assumed to pose either moderate or high risk to ground water, even if, as is true in one case in the phosphoric acid sector, the environmental conditions indicate a low risk. Therefore, all facilities meet the same requirements under both Subtitle D-Plus and under Subtitle C-Minus; ground-water monitoring, a practice that is not required under the low risk Subtitle D-plus scenario, is assumed to be required in all cases.

Phosphogypsum

Subtitle C

Under Subtitle C standards, of hazardous waste that is managed on-site must meet the standards codified at 40 CFR Parts 264 and 265 for hazardous waste treatment, storage, and disposal facilities. The Agency has assumed that the phosphogypsum can and will be managed separately from the other special waste, process wastewater; non-hazardous process wastewater is assumed to be used to transport the phosphogypsum to the management unit. Because phosphogypsum is an inorganic solid that is transported in slurry form, the management practice of choice under Subtitle C is surface impoundment disposal. EPA has determined that because of Subtitle C closure requirements, existing waste management units (gypsum stacks) would not be permissible, because of the steep (nearly vertical) angles with which they are constructed. Closure of such units would require extensive contouring and regrading (so that they could be capped effectively), such that the total area occupied by the unit at closure would greatly exceed the space occupied during its operating life. The scenario examined here involves construction of a double-lined Subtitle C surface impoundment of significant size. The gypsum would be slurried to this impoundment in much the same way as it is currently slurried to gypsum stacks. Following settling of the suspended phosphogypsum, the transport water would be removed and piped back to the process operation for reuse, just as it is under current practice.

Subtitle C-Minus

Two primary differences are assumed to exist between full Subtitle C and Subtitle C-minus. The first is the assumption that facilities could use gypsum stacks if their use is less costly than using disposal impoundments. The second difference is the facility-specific application of tailored requirements based on potential risk to groundwater at affected facilities. Under the C-Minus scenario, as well as the Subtitle D-Plus scenario described below, the degree of potential risk of contaminating ground-water resources was used as a decision criterion in determining what level of protection (e.g., liner and closure cap requirements) would be necessary to protect human health and the environment. Ten of the 11 facilities assumed to generate potentially hazardous phosphogypsum were determined to have a high potential to contaminate ground-water resources; the eleventh was considered a low risk location.

When risk to ground water is high, facilities are assumed to be required to manage the waste in stacks lined with double synthetic liners and leachate collection and detection systems. As none of the ten facilities in high risk locations currently operate this type of unit, all would, under Subtitle C-minus, be required to build new stacks. In addition to the double composite liners, the stacks in high risk locations are required to have run-on/run-off controls and ground-water monitoring wells; both practices must be continued through the post-closure care period. In addition, the units must undergo formal closure, including a cap of topsoil and grass over a composite liner. Post-closure care must be maintained (e.g., mowing and general cap maintenance, and ground-water monitoring) for a period of 30 years.

At three of the ten facilities, where depth to groundwater allows for relatively deep impoundment construction, surface impoundment disposal of phosphogypsum is estimated to be the least cost management alternative. Composite-lined impoundments, requiring composite caps at closure, were assumed to be used at these facilities.

Chevron's Wyoming facility, the only facility in a low risk area (and the only facility at which phosphogypsum samples were determined to be EP toxic) was allowed to continue using its currently operating unit; the operator was assumed, however, to be required to install a ground-water monitoring system.

Subtitle D-Plus

As under both Subtitle C scenarios, facility operators under the Subtitle D-Plus scenario would be required to ensure that hazardous contaminants do not escape into the environment. Like the Subtitle C-Minus scenario, facility-specific requirements are applied to allow the level of protection to increase as the potential risk to ground water increases. Under Subtitle D-Plus, the facilities are also allowed to operate gypsum stacks. The stacks do not require capping at closure under this scenario, under the assumption that the natural crusting of the gypsum that occurs as the material dries would be adequately protective. Because no capping, and therefore, no reduced slope angles, are required, the stacks are built with the same dimensions as the currently operating stacks, minimizing the total basal area required and, therefore, potentially decreasing the cost of compliance. Stacks at the ten high-risk facilities are assumed to require

composite liners, single leachate collection systems, and ground-water monitoring. The one low-risk facility is assumed to continue operating its current stack. All eleven facilities are assumed to be required to install run-on/run-off controls and would continue the practice through the post-closure care period.

12.6.2 Cost Impact Assessment Results

Process Wastewater

Results of the cost impact analysis for the process wastewater generated by phosphoric acid facilities are presented by facility and regulatory scenario in Exhibit 12-9

. Of the 21 facilities generating process wastewater, all are expected to incur costs under the Subtitle C regulatory scenario. Under this scenario, the annualized regulatory compliance costs would be \$3.2 to \$26.3 million greater than the baseline waste management costs, with a sector total of \$225 million per year over baseline costs. Annualized new capital expenditures range from \$1.1 to 11.7 million with a sector total of \$101.8 million. At the majority of the facilities, capital costs account for 45 percent of the total annualized compliance cost, with the cost of wastewater tank treatment dominating overall costs.

Under the Subtitle C-Minus and D-Plus scenarios, the annualized compliance costs drop only slightly, due to relaxed technical standards for operation of the surge ponds used to hold the wastewater prior to treatment. Annualized compliance costs under Subtitle C-Minus range from \$3.0 to \$25.6 million; the sector total is estimated to be \$215 million. Annualized costs under Subtitle D-Plus are nearly identical, with a

sector total estimated at \$213 million; the slight difference is due to differences in assumed permitting requirements and associated costs.

Phosphogypsum

Results of the cost impact analysis for the phosphogypsum generated by phosphoric acid producers are presented by facility and regulatory scenario in Exhibit 12-10

. Of the 21 facilities generating phosphogypsum, a maximum of 11 may generate potentially hazardous waste and incur costs under the Subtitle C regulatory scenario. Under this scenario, the annualized regulatory compliance costs would range, for those eleven facilities, from \$10.8 million to \$185 million over and above baseline waste management costs, with a sector total of \$684 million per year. Annualized new capital expenditures account for the vast majority (80 percent) of incremental costs, ranging from \$8.4 million to \$147 million greater than baseline, with a sector total of \$542 million. The primary reason for these extreme compliance-related capital expenditures is the large size of the Subtitle C disposal impoundments that would be needed to contain a 15 year accumulation of phosphogypsum at most facilities.

Under the less rigorous, risk related technical requirements of the Subtitle C-Minus scenario, the annualized compliance costs would be \$1.2 million to \$65.3 million greater than the baseline waste management costs, with a sector total of \$216.7 million per year. Annualized new capital expenditures would range from \$0.4 to \$51.2 million, with a sector total of \$171 million. The decrease in compliance costs between the two Subtitle C scenarios is primarily a function of the assumption that modified stacks could be used under the Subtitle C-Minus scenario; the primary design modification involves a decrease in the slope of the stacks to allow for effective capping at closure. In addition, facilities located in low risk areas (one in this sector) could continue to operate their current stacks, and would simply be required to retrofit run-on/run-off controls and install ground-water monitoring systems. Facilities in high risk areas (the remaining ten facilities), incur higher costs due to requirements for double liners/leachate collection systems, increased basal area due to limitations on slope, and capping at closure. For three facilities, the costs of building new stacks that complied with these requirements were estimated to be higher than those of building similarly protective disposal impoundments; accordingly, for costing purposes, these facilities were assumed to build impoundments rather than gypsum stacks.

Under the Subtitle D-Plus regulatory scenario, the annualized compliance costs would be \$0.48 to \$62.2 million greater than the baseline waste management costs, with a sector total of \$48.7 million per year. Annualized new capital expenditures would range from \$0.1 to \$52 million, with a sector total of \$166 million. The distribution of costs is identical to that of the C-Minus scenario, while the overall magnitude of the costs is about 25 percent less. The primary reason for the decrease is that, because no capping is required, facilities can operate stacks with slopes identical to current practices; this reduces the basal area needed and hence, the costs of liners and leachate collection systems. In addition, the actual costs of capping are not incurred. As under Subtitle C-Minus, the one facility located in a low risk area is assumed to continue operating its current stack, but would retrofit needed controls. Ground-water monitoring is not required for this facility, due to its low risk location.

12.6.2 Financial and Economic Impact Assessment

In order to evaluate the ability of affected facilities to bear these estimated regulatory compliance costs, EPA performed an impact assessment which consists of three steps. First, the Agency compared the estimated compliance costs to the financial strength of each facility, to assess the relative magnitude of the financial burden that would be imposed in the absence of changes in supply, demand, or price. Next, EPA conducted a qualitative evaluation of the salient market factors which affect the competitive position of the phosphoric acid producers, in order to determine whether compliance costs could be passed on to labor markets, suppliers of raw materials, or consumers. Finally, the Agency combined the results of the first two steps to predict the net compliance-related economic impacts which would be experienced by the facilities

being evaluated. The methods and assumptions used in this analysis are described in Chapter 2 and in Appendices E-3 and E-4 to this report.

Financial Ratio Analysis

Process Wastewater

EPA believes that costs of compliance under full Subtitle C would have at least marginally significant impacts on all 21 facilities, as reflected by the screening ratio results in Exhibit 12-11

. Annual compliance costs as a percent of value of shipments or value added are expected to be from one to five percent at 18 of the 21 facilities; for the remaining facilities, the screening ratio results range from five to seven percent. The compliance capital as a percent of annual sustaining capital is high for all 21 facilities, ranging from 14 to 73 percent. The financial impacts under prospective Subtitle C-Minus and D-Plus regulation would be similar in distribution and magnitude to those of the Subtitle C scenario.

Phosphogypsum

Regulation under Subtitle C would have a highly significant financial impact on any phosphoric acid facilities whose phosphogypsum is found to be hazardous (phosphogypsum was EP toxic at only one facility that was sampled, therefore, the remaining ten facilities for which costs were estimated might or might not actually experience impacts).
A s s h o w n i n E x h i b i t 1 2 - 1 2

, the annualized incremental costs associated with waste management under Subtitle C represent 4 to 40 percent of both the value added and the value of shipments for all affected facilities generating potentially hazardous phosphogypsum. Moreover, the ratio of annual capital costs to annual sustaining capital investments also suggests severe impacts for these facilities, with screening ratio results ranging from 80 to 700 percent.

The financial impacts under Subtitle C-Minus regulation would be much less than under the full Subtitle C scenario. One facility, located in a low risk area, is estimated to incur no impacts under Subtitle C-Minus. Interestingly, this is the only facility for which waste sampling actually indicated EP toxicity. For the remaining ten facilities, impacts on the value of shipments or value added range from 3 to 13 percent.

Estimation of impacts under the Subtitle D-Plus scenario indicates that for three of the ten affected facilities, there is no difference from the Subtitle C-Minus scenario (the facility in the low risk area again experiences no impacts). One of the remaining seven facilities experiences only slightly lower impacts (5 percent less than C-Minus); the remaining six facilities experience reductions in the magnitude of impacts of 43 percent from the C-Minus scenario. Annualized capital as a percent of sustaining capital investments is high even under the Subtitle D-Plus scenario; screening ratio results for the ten affected facilities range from 55 to 229 percent.

Market Factor Analysis

General Competitive Position

The U.S. is the world's leading producer of phosphoric acid, the primary use of which is in fertilizers; other uses for phosphoric acid include nutrient supplements for animal feeds, builders for detergents, water softeners, additives for food, and pharmaceuticals. Domestic acid production is based on large quantities of high-quality phosphate rock reserves, located principally in Florida and North Carolina. These deposits provide abundant feedstock for high-quality phosphoric acid production. In recent years, Morocco has become the United State's main competitor in international markets. This competition has resulted in a downward price trend for phosphate in these markets. The fact that the U.S. is a major exporter of phosphate rock is an indication of the quality and relative cost of its phosphate reserves. However, low-cost, high-quality deposits do not guarantee profits in the phosphate rock and phosphoric acid markets. During difficult economic times, the use of phosphoric acid can decline despite being offered at a fairly low price. Fertilizer

use is in part discretionary, and selection of types and amounts of various fertilizer types can vary. Despite its fairly competitive position versus other world suppliers, therefore, the profit margins for phosphoric acid and phosphate rock may often be somewhat restricted.

Throughout the 1990's, domestic production of phosphoric acid is expected to remain constant, while foreign production is expected to increase by less than 2.5 percent per year. Both domestic and foreign demand for phosphoric acid are expected to grow by less than 2.5 percent per year during the 1990's.

Potential for Compliance Cost Pass-Through

Labor Markets. There has been considerable restructuring in the phosphate industry with some associated wage concessions. The potential for further labor concessions is not known.

Lower Prices to Suppliers. The ability to pass through costs to input markets is not particularly relevant because the major phosphoric acid producers are integrated.

Higher Prices. Higher prices are generally difficult to impose except during periods of worldwide prosperity. The price of phosphate rock and phosphoric acid depends a great deal on competition from Morocco, the price of alternative fertilizers, and the use of slow release fertilizers.

Evaluation of Cost/Economic Impacts

EPA believes that regulation of phosphogypsum as a hazardous waste under RCRA Subtitle C would impose potentially severe impacts on facilities at which this waste exhibits EP toxicity; the number of such facilities is highly uncertain but is at least one and likely to be two or three. Mitigation of the severe cost impacts that would be experienced by the affected phosphoric acid producers under Subtitle C would be unlikely, because of the limited potential for compliance cost pass-through (at least 10 of the 21 active domestic producers would experience no impacts), and the operational reality that a substantial quantity (approximately five tons) of phosphogypsum is generated for every ton of phosphoric acid produced using the wet process. Therefore, EPA believes that regulation of phosphogypsum as a hazardous waste could pose a threat to the continued operation of any producer whose phosphogypsum tested EP toxic. Regulation under Subtitle C-Minus would also impose significant impacts at most facilities. The prospect of regulation of phosphogypsum under the Subtitle D-Plus scenario examined here would be unlikely to pose a threat to the continued viability of the majority of the phosphoric acid facilities. For 18 of the 21 active producers, no significant impacts would be incurred in managing phosphogypsum under Subtitle D-Plus regulations. At least three facilities, however, and one in particular, would be expected to incur significant impacts in managing phosphogypsum even under Subtitle D-Plus, potentially posing a threat to the economic viability of these facilities. One of those three facilities, however, is currently planning/constructing a new stack which is expected to be lined and employ a leachate collection system; estimated costs in meeting Subtitle D-Plus requirements may therefore actually have been incurred by that facility while this report was being prepared; in that event, Subtitle D-Plus regulation would not impose any costs or impacts on this facility.

The Agency also expects that regulation of process wastewater as a hazardous waste under both Subtitle C and C-Minus regulation could potentially pose a threat to the economic viability of affected domestic phosphoric acid producers, based on estimated compliance cost impacts; estimated impacts under the Subtitle D-Plus scenario are marginally lower. Because, however, all producers are expected to be affected, there is a greater potential for passing through costs to consumers in the form of higher prices for domestically produced acid than there would be if phosphogypsum were to be regulated as a hazardous waste. Eight of the 21 facilities managing potentially hazardous process wastewaters are predicted to incur significant impacts under the Subtitle D-Plus scenario. The significance of these impacts, as discussed above, is diminished by the possibility of the operators reducing waste generation or physically separating waste streams generated from different operations, in order to dramatically reduce the actual volume of water that would be hazardous and hence require treatment.

12.7 Summary

As discussed in Chapter 2, EPA developed a step-wise process for considering the information collected in response to the RCRA §8002(p) study factors. This process has enabled the Agency to condense the information presented in the previous six sections of this chapter into three basic categories. For each special waste, these categories address the following three major topics: (1) the potential for and documented danger to human health and the environment; (2) the need for and desirability of additional regulation; and (3) the costs and impacts of potential Subtitle C regulation.

Potential and Documented Danger to Human Health and the Environment

The intrinsic hazard of phosphogypsum is moderate to high in comparison to other mineral processing wastes studied in this report. Based on EP leach test results, 2 out of 28 samples (from 1 out of 8 facilities tested) contain chromium concentrations in excess of the EP toxicity regulatory levels. Chromium concentrations measured in SPLP (EPA Method 1312) leachate, however, were well below the EP regulatory levels. Phosphogypsum contains 12 constituents that exceed one or more of the screening criteria used in this analysis by more than a factor 10. Phosphogypsum solids may also contain uranium-238 and radium-226 in concentrations that could pose an unacceptably high radiation risk if the waste is allowed to be used in an unrestricted manner. For this reason, as part of its recently promulgated airborne emission standards for radionuclides (54 FR 51654, December 15, 1989), EPA has banned the off-site use or disposal of phosphogypsum in anything other than a stack or mine, with a limited waiver for agricultural uses. (See also 55 FR 13480, April 10, 1990.)

The intrinsic hazard of phosphoric acid process wastewater is relatively high compared to other mineral processing wastes studied in this report. Measurements of pH in 42 out of 68 process wastewater samples (from 10 of 14 facilities tested) indicated that the wastewater was corrosive, sometimes with pH values as extreme as 0.5. Based on EP leach test results, 19 out of 30 samples contain cadmium concentrations in excess of the EP toxicity regulatory level. In addition, 3 of 30 samples contain chromium concentrations in excess of EP toxicity regulatory levels. Phosphoric acid process wastewater also contains four constituents at concentrations that exceed one or more of the screening criteria used in this analysis by more than a factor of 1,000 and another 15 constituents exceed at least one relevant criterion by more than a factor of 10, including three radionuclides (i.e., gross alpha and beta radiation and radium-226).

Numerous documented cases of ground-water contamination indicate that phosphogypsum and process wastewater constituents have been released to ground and surface water at a number of facilities, and, at some sites, have migrated off-site to potable drinking water wells in concentrations that are well above criteria for the protection of human health. For example, in central Florida, the State Department of Environmental Regulation has initiated enforcement actions at all 11 active phosphoric acid production facilities because phosphogypsum stacks and process wastewater ponds have caused ground-water contamination above drinking water standards at the plant boundary or beyond. Based on the evidence of documented damages, EPA concludes that management of phosphogypsum and process wastewater in stacks and unlined ponds can release contaminants to the subsurface and that stack and dike failure can release contaminants to nearby surface waters. The combination of the intrinsic hazard of these wastes and the documented evidence of releases indicates that current management of phosphogypsum and phosphoric acid process wastewater may threaten human health through drinking water exposures, threaten aquatic life, and may render water resources unsuitable for potential consumptive uses. Although EPA estimates that phosphogypsum stacks pose an MEI lifetime air pathway cancer risk of as much as 9×10^{-5} as a result of radon emissions from the stacks, (with minor contributions from radioactive and nonradioactive constituents in windblown dust) the Agency concluded in its analysis of NESHAPs for phosphogypsum stacks that this level of risk is "acceptable."¹⁴² Consequently, EPA promulgated a

¹⁴² 54 FR 51675. December 15, 1989.

work practice standard for radon flux from phosphogypsum stacks that the Agency "belives existing stacks meet... without the need for additional control technology."¹⁴³

Likelihood That Existing Risks/Impacts Will Continue in the Absence of Subtitle C Regulation

At many active phosphoric acid production plants, current waste management practices and environmental conditions may allow contaminant releases and risks in the future in the absence of Subtitle C regulation. For example, the stacks and ponds are typically unlined and in the Southeast, where the phosphoric acid industry is most heavily concentrated, and ground water occurs in relatively shallow aquifers. While these surficial aquifers are not typically used for drinking water purposes, they frequently are hydraulically connected to aquifers or surface waters that supply drinking water. Similarly, catastrophic stack and dike failures and long-term seepage from stacks and ponds have released process wastewater and phosphogypsum constituents directly from management units to surface waters. Therefore, environmental releases can occur and, considering the intrinsic hazard of the wastes, significant exposures could occur if contaminated ground water is used as a source of drinking water.

The phosphoric acid production industry recently has been recovering from low production levels in the mid-1980's and may continue to expand somewhat in the future if fertilizer use continues to grow in response to increases in crop prices and planted acreage. Increases in production would likely be provided by increased capacity utilization at active plants (e.g., in 1988 three plants operated at utilization rates of 16 to 38 percent) and the reactivation of plants that are presently on standby. Therefore, if phosphoric acid production does increase, use of existing waste management units (both those at facilities evaluated in this analysis and those at idle facilities that were not included in this analysis) would expand, potentially increasing release potential and posing greater threats to human health and the environment. However, given the large quantities of these wastes, and the ban of off-site use of phosphogypsum,¹⁴⁴ it is unlikely that these wastes will be used or disposed in significant quantities at off-site locations in the future.

State regulation of phosphoric acid production wastes varies considerably among the seven states in which active plants are located, but requirements in most states may not be sufficient to control releases from existing units and prevent threats to human health and the environment. For example, relatively comprehensive solid waste regulations in Louisiana and Florida (under development) require liners and specify closure requirements for new and expansions of existing stacks, but the state programs provide controls for releases from existing units only through requirements for ground-water monitoring and performance standards that in some cases allow off-site contamination. In North Carolina, phosphogypsum and process wastewater are not defined as solid wastes, and are not subject to any solid waste regulations, though discharges from waste management units must be permitted under the state's EPA-approved NPDES program. In summary, state regulatory controls may not be sufficient to prevent releases of phosphogypsum and process wastewater constituents from existing units, and in only a few states are regulations that specify construction and operation standards in place or under development.

Costs and Impacts of Subtitle C Regulation

EPA has evaluated the costs and associated impacts of regulating both phosphogypsum and process wastewater from phosphoric acid production as hazardous wastes under RCRA Subtitle C. EPA's waste characterization data indicate that phosphogypsum exhibited the hazardous waste characteristic of EP toxicity at only one of the eight active facilities for which sampling data were available. EPA's data also indicate that process wastewater is either corrosive or EP toxic or both at each facility for which sampling data were available. Because of the relatively high potential for contamination as a result of the environmental settings of most phosphoric acid sites (e.g., shallow ground water) and the large number of damage cases associated with phosphoric acid production wastes, EPA employed the conservative assumption that phosphogypsum would be EP toxic at untested facilities, and that process wastewater

¹⁴³ Ibid.

¹⁴⁴ Ibid.

would be both corrosive and EP toxic at untested facilities; the Agency's cost and impact estimates reflect this assumption and therefore probably overestimate the impacts of prospective regulation.

For phosphogypsum, costs of regulatory compliance under the full Subtitle C scenario exceed \$10 million annually at all affected facilities and range as high as \$185 million per year; these costs would impose potentially significant economic impacts on the operators of all affected plants. Application of the more flexible Subtitle C-Minus regulatory scenario would result in compliance costs that, on average, are approximately 60 percent lower, ranging from about \$1 million to more than \$65 million annually. Costs under the Subtitle D-Plus scenario are approximately 19 percent lower than under Subtitle C-Minus, because of further relaxation of waste management unit design and operating standards.

Subtitle C compliance costs would comprise a significant fraction of the value of shipments of and value added by phosphoric acid production operations at most affected facilities; ratios at seven of the eleven affected facilities exceed ten percent (five have ratios at or above 20 percent), while the remaining four exceed four percent. Compliance cost ratios under the Subtitle C-Minus and Subtitle D-Plus scenarios generally range from three to eight percent, though ratios at Agrico's Uncle Sam (LA) plant exceed eleven percent even under the least stringent scenario. EPA's economic impact analysis suggests that the domestic phosphoric acid industry is currently stronger than it has been in recent years, but would probably not be able to pass through compliance costs in the form of significantly higher prices to product consumers. Moreover, because not all domestic producers would be affected or affected equally, it is improbable that facilities experiencing high compliance costs would be able to obtain higher product prices in any case, given the relatively low rate of industry capacity utilization (77 percent overall in 1988). Therefore, if phosphogypsum were removed from the Mining Waste Exclusion, facilities at which this material was EP toxic might face new waste management costs (even under modified Subtitle C standards) that could threaten their long-term profitability and hence, their economic viability.

It is worthy of note that some impacts would be likely to occur even in the absence of a decision to remove phosphogypsum from the Mining Waste Exclusion, because adequately protective waste management standards under a Subtitle D program would require the construction of new waste management units at most facilities, implying significant new capital expenditures.

Based upon existing waste characterization data, EPA believes that all of the 21 facilities generating wet process phosphoric acid process wastewater might incur costs under a change in the regulatory status of this waste. Annualized regulatory compliance costs under Subtitle C would exceed \$225 million, ranging from \$4.7 to \$26.3 million. Annualized new capital expenditures would account for approximately 45 percent of the total, with the cost of wastewater tank treatment dominating overall costs. Under the Subtitle C-Minus and D-Plus scenarios, the annualized compliance costs drop only slightly (\$10-12 million in aggregate), due to relaxed technical standards for operation of the surge ponds used to hold the wastewater prior to treatment. The Agency expects that regulation of process wastewater as a hazardous waste under both Subtitle C and C-Minus regulation could potentially pose a threat to the economic viability of affected domestic phosphoric acid producers, based on estimated compliance cost impacts; estimated impacts under the Subtitle D-Plus scenario are marginally lower. The significance of these impacts might be diminished by the possibility of the operators reducing waste generation or physically separating waste streams generated from different operations, in order to reduce the actual volume of water that would be hazardous and hence require treatment.

Finally, EPA believes that incentives for recycling or utilization of phosphoric acid production wastes would be mixed if a change in the regulatory status of this waste were to occur. The predominant management alternative to disposal of phosphogypsum has been off-site use in construction applications and in agriculture. Because of the recently promulgate NESHAP banning such use, however, EPA expects that phosphogypsum will now be disposed on-site, regardless of the RCRA requirements that may be applied to such disposal, i.e., regulation under Subtitle C would affect only the costs of phosphogypsum management, not the type(s) of management techniques employed. Direct recycling of phosphogypsum for additional product recovery is not a viable option, and process changes that might affect the chemical properties of the material as well as purification methods have been employed with variable success. It is likely that in response to new regulatory requirements, facility operators would develop and implement measures to render their phosphogypsum non-EP toxic. Process wastewater is currently internally recycled at all active facilities. The potential for reducing the amount of water used and/or significantly reducing the total quantities of corrosive or

otherwise hazardous substances currently found in process wastewater is extremely limited, given the nature of wet process phosphoric acid production operations.

Exhibit 12-7
Effect of Purification Methods on
Ra-226 Concentrations in Phosphogypsum, Listed by State

State	Phosphogypsum Generated in 1988 (MT) ^(a)	Observed Ra-226 Content in Phosphogypsum (pCi/g) ^(b)	Ra-226 Content After Purification by Physical Separation (pCi/g)	Ra-226 Content After Purification by Acid Digestion	
				Using Anhydrite Phosphogypsum (pCi/g)	Using Hemihydrate Phosphogypsum (pCi/g)
Florida	29,777,000	5.9 - 38 ^(c,d)	4 - 27	3	1
Idaho	2,646,000	7.9 - 23 ^(d)	6 - 16	3	1
Louisiana	7,280,000	1.4 - 257 ^(e)	1 - 180	3	1
Mississippi	474,000	5.9 - 38 ^(d,e)	4 - 27	3	1
North Carolina	5,425,250	4.3 - 4.6	3	3	1
Texas	1,157,000	13.2 - 15.0	9 - 10.5	3	1
Wyoming	836,000			3	1

(a) Company responses to EPA's "National Survey of Solid Wastes from Mineral Processing Facilities," conducted in 1989.

(b) 1989 Waste Characteristic data provided by industry in response to RCRA 3007.

(c) May, Alexander and John W. Sweeney, Assessment of Environmental Impacts Associated with Phosphogypsum in Florida, prepared for the U.S. Department of Interior, Bureau of Mines, RI 8639, p. 8.

(d) EG&G Idaho, Inc., Evaluation of Relative Hazards of Phosphate Products and Wastes, prepared for the U.S. Department of Energy, DOE Contract No. DE-AC07-76ID01570, March 1984, p. 18.

(e) The phosphate rock originates in central Florida.

Exhibit 2-8
Effect of Purification Methods on
Ra-226 Concentrations in Phosphogypsum, Listed by Facility

Facility	State	Phosphogypsum Generated In 1988 (MT/YR) ^(a)	Observed Ra-226 Content in Phosphogypsum (pCi/g) ^(b)			Ra-226 Content After Purification by Physical Separation (pCi/g)	Ra-226 Content After Purification by Acid Digestion	
			Min	Med	Max		Using Anhydrite Phosphogypsum (pCi/g)	Using Hemihydrate Phosphogypsum (pCi/g)
Agrico in Unlce Sam	LA	4,100,000					3	1
Agrico in Donaldson	LA	2,580,000	90	182.5	63 - 80	63 - 180	3	1
Arcadian in Geismar	LA	600,000	1.4	15.5	1 - 14	1 - 14	3	1
CF Chemicals in Bartow	FL	140,000	---	---	---	---	3	1
Conserv in Nichols	FL	1,100,000	5.9	5.9	4	4	3	1
IMS Fertilizer in Mulberry	FL	6,800,000	19	27	13 - 26	13 - 26	3	1
JR Simplot in Pocatello	ID	1,457,000 ^(c)	7.9		6 - 16	6 - 16	3	1
Tesagulf in Auroa	NC	5,425,250	4.3	4.5	3	3	3	1
Mobil Mining in Pasadena	TX	1,157,000	13.2	14.1	9 - 10.5	9 - 10.5	3	1

- (a) Company responses to EPA's "National Survey of Solid Wastes from Mineral Processing Facilities," conducted in 1989.
(b) 1989 Waste Characteristic data provided by industry in response to RCRA 3007.
(c) Reported value is confidential; estimate made using average waste to product ratio and facility capacity.

Exhibit 12-9
Compliance Cost Analysis Results for Management of
Process Wastewater from Phosphoric Acid Production^(a)

Facility	Baseline Waste Management Cost	Incremental Costs of Regulatory Compliance								
		Subtitle C			Subtitle C-Minus			Subtitle D-Plus		
		Annual Total (\$ 000)	Total Capital (\$ 000)	Annual Capital (\$ 000)	Annual Total (\$ 000)	Total Capital (\$ 000)	Annual Capital (\$ 000)	Annual Total (\$ 000)	Total Capital (\$ 000)	Annual Capital (\$ 000)
Agri Chem - Bartow, FL	296	5,849	15,488	2,311	5,537	13,781	2,056	5,434	13,781	2,056
Agrico Chemical - Donaldsonville, LA	287	12,131	39,213	5,851	11,677	36,708	5,477	11,677	36,708	5,477
	298	11,098	32,239	4,811	10,654	29,795	4,446	10,551	29,795	4,446
Agrico Chemical - Mulberry, FL	314	15,541	50,321	7,509	14,975	47,193	7,042	14,872	47,193	7,042
Agrico Chemical - Uncle Sam, LA	247	5,375	16,180	2,414	5,162	15,022	2,241	5,059	15,022	2,241
Arcadian - Geismar LA	320	22,313	68,915	10,283	21,080	62,058	9,260	21,080	62,058	9,260
Central Phosphates - Plant City, FL	809	6,950	19,436	2,900	6,610	17,578	2,623	6,507	17,578	2,623
CF Chemicals - Bartow, FL	281	4,760	12,439	1,856	4,504	11,043	1,648	4,402	11,043	1,648
Chevron - Rock Springs, WY	261	3,213	8,004	1,194	3,048	7,110	1,061	2,946	7,110	1,061
Conserv - Nichols, FL	285	6,817	18,332	2,735	6,465	16,399	2,447	6,362	16,399	2,447
Farmland Industries - Bartow, FL	835	16,544	51,094	7,624	15,633	46,047	6,871	15,530	46,047	6,871
Gardinier - Riverview, FL	326	26,309	79,067	11,798	25,619	75,236	11,226	25,516	75,236	11,226
IMC Fertilizer - Mulberry, FL	276	8,023	24,179	3,608	7,638	22,068	3,293	7,535	22,068	3,293
Mobil Mining - Pasadena, TX	519	7,871	26,091	3,893	7,491	24,013	3,583	7,388	24,013	3,583
Nu-South Industries - Pascagoula, MS	269	5,743	16,424	2,451	5,464	14,899	2,223	5,361	14,899	2,223
Nu-West - Soda Springs, ID	824	12,789	36,856	5,499	12,256	33,912	5,060	12,153	33,912	5,060
Occidental Chemical - White Springs, FL	524	6,506	17,902	2,671	6,192	16,183	2,415	6,089	16,183	2,415
	549	10,719	36,137	5,392	10,197	33,262	4,963	10,094	33,262	4,963
Royster - Mulberry, FL	520	12,948	37,186	5,549	12,434	34,356	5,126	12,331	34,356	5,126
Royster - Palmetto, FL	555	5,369	14,958	2,232	5,093	13,452	2,007	4,990	13,452	2,007
Seminole Fertilizer - Bartow, FL	303	18,166	62,169	9,276	17,393	57,893	8,638	17,290	57,893	8,638
JR Simplot - Pocatello, ID										
Texasgulf - Aurora, NC										
Total:	8,897	225,033	682,629	101,857	215,121	628,007	93,706	213,167	628,007	93,706
Average:	424	10,716	35,506	4,850	10,244	29,905	4,462	10,151	29,905	4,462

(a) Values reported in this table are those computed by EPA's cost estimating model and are included for illustrative purposes. The data, assumptions, and computational methods underlying these values are such that EPA believes that the compliance cost estimates reported here are precise to two significant figures.

Facilities evaluated here as generating potentially hazardous waste include those for which no sampling data exists.

Exhibit 12-10
Compliance Cost Analysis Results for Management of
Phosphogypsum from Phosphoric Acid Production^(a)

Facility	Baseline Waste Management Cost	Incremental Costs of Regulatory Compliance								
		Subtitle C			Subtitle C-Minus			Subtitle D-Plus		
	Annual Total (\$ 000)	Annual Total (\$ 000)	Total Capital (\$ 000)	Annual Capital (\$ 000)	Annual Total (\$ 000)	Total Capital (\$ 000)	Annual Capital (\$ 000)	Annual Total (\$ 000)	Total Capital (\$ 000)	Annual Capital (\$ 000)
Agri Chem - Bartow, FL	409	17,310	90,806	13,549	11,760	60,101	8,968	11,645	64,067	9,560
Agrico Chemical - Mulberry, FL	1,057	41,386	220,518	32,904	20,455	110,917	16,550	11,906	66,627	9,942
Agrico Chemical - Uncle Sam, LA	3,856	99,755	534,386	79,737	65,361	343,515	51,257	62,242	352,204	52,553
Central Phosphates - Plant City, FL	1,547	185,043	985,328	147,02	30,180	164,700	24,575	17,887	101,203	15,101
Chevron - Rock Springs, WY	434	10,885	56,316	3	1,276	2,696	402	483	875	131
Gardinier - Riverview, FL	694	117,107	621,515	8,403	21,409	114,562	17,094	12,750	70,161	10,469
Mobil Mining - Pasadena, TX	962	46,859	247,207	92,738	12,877	68,198	10,176	7,428	40,059	5,977
Nu-South Industries - Pascagoula, MS	710	62,428	330,400	36,886	13,080	69,336	10,346	7,414	40,255	6,007
Nu-West - Soda Springs, ID	1,811	11,989	62,746	49,300	8,063	41,055	6,126	7,960	41,055	6,126
Occidental Chemical - White Springs, FL	1,298	27,712	149,079	9,363	18,916	100,310	14,968	18,813	100,310	14,968
Royster - Palmetto, FL	334	64,115	338,993	22,245	13,362	70,715	10,552	7,661	41,498	6,192
				50,582						
Total:	13,112	684,588	3,637,295	542,73	216,73	1,146,105	171,013	166,188	918,313	137,024
Average:	1,192	62,235	330,663	0	8	104,191	15,547	15,108	83,483	12,457
				49,339	19,703					

(a) Values reported in this table are those computed by EPA's cost estimating model and are included for illustrative purposes. The data, assumptions, and computational methods underlying these values are such that EPA believes that the compliance cost estimates reported here are precise to two significant figures.

Facilities evaluated here as generating potentially hazardous waste include those for which no sampling data exists.

Exhibit 12-11
Significance of Regulatory Compliance Costs for Management of
Process Wastewater from Phosphoric Acid Production^(a)

Facility	Subtitle C			Subtitle C-Minus			Subtitle D-Plus		
	CC/VOS	CC/VA	IR/K	CC/VOS	CC/VA	IR/K	CC/VOS	CC/VA	IR/K
Agri Chem - Bartow, FL	1.69%	1.87%	16.0%	1.60%	1.77%	14.2%	1.57%	1.74%	14.2%
Agrico Chemical - Donaldsonville, LA	3.06%	3.40%	35.5%	2.95%	3.28%	33.2%	2.95%	3.28%	33.2%
Agrico Chemical - Mulberry, FL	3.37%	3.74%	35.1%	3.23%	3.59%	32.4%	3.20%	3.56%	32.4%
Agrico Chemical - Uncle Sam, LA	2.83%	3.14%	32.8%	2.73%	3.03%	30.8%	2.71%	3.01%	30.8%
Arcadian - Geismar, LA	3.67%	4.08%	39.6%	3.53%	3.92%	36.8%	3.46%	3.84%	36.8%
Central Phosphates - Plant City, FL	3.91%	4.34%	43.2%	3.69%	4.10%	38.9%	3.69%	4.10%	38.9%
CF Chemicals - Bartow, FL	6.32%	7.03%	63.4%	6.02%	6.68%	57.3%	5.92%	6.58%	57.3%
Chevron - Rock Springs, WY	2.47%	2.75%	23.1%	2.34%	2.60%	20.5%	2.28%	2.54%	20.5%
Conserv - Nichols, FL	1.77%	1.97%	15.8%	1.68%	1.87%	14.1%	1.62%	1.80%	14.1%
Farmland Industries - Bartow, FL	1.55%	1.72%	14.9%	1.47%	1.63%	13.4%	1.45%	1.61%	13.4%
Gardinier - Riverview, FL	4.07%	4.52%	45.1%	3.85%	4.27%	40.6%	3.82%	4.25%	40.6%
IMC Fertilizer - Mulberry, FL	2.22%	2.46%	23.9%	2.16%	2.40%	22.7%	2.15%	2.39%	22.7%
Mobil Mining - Pasadena, TX	3.65%	4.06%	39.4%	3.48%	3.86%	36.0%	3.43%	3.81%	36.0%
Nu-South Industries - Pascagoula, MS	4.77%	5.31%	56.7%	4.54%	5.05%	52.2%	4.48%	4.98%	52.2%
Nu-West - Soda Springs, ID	2.61%	2.90%	26.8%	2.49%	2.76%	24.3%	2.44%	2.71%	24.3%
Occidental Chemical - White Springs, FL	1.98%	2.20%	20.5%	1.90%	2.11%	18.8%	1.88%	2.09%	18.8%
Royster - Mulberry, FL	2.47%	2.74%	24.4%	2.35%	2.61%	22.0%	2.31%	2.57%	22.0%
Royster - Palmetto, FL	6.09%	6.76%	73.6%	5.79%	6.43%	67.7%	5.73%	6.37%	67.7%
Seminole Fertilizer - Bartow, FL	2.91%	3.23%	30.0%	2.80%	3.11%	27.7%	2.77%	3.08%	27.7%
JR Simplot - Pocatello, ID	2.49%	2.76%	24.8%	2.36%	2.62%	22.3%	2.31%	2.57%	22.3%
Texasgulf - Aurora, NC	2.01%	2.24%	24.7%	1.93%	2.14%	23.0%	1.91%	2.13%	23.0%

CC/VOS = Compliance Costs as Percent of Sales
CC/VA = Compliance Costs as Percent of Value Added
IR/K = Annualized Capital Investment Requirements as Percent of Current Capital Outlays

(a) Values reported in this table are based upon EPA's compliance cost estimates. The Agency believes that these values are precise to two significant figures.

Facilities evaluated here as generating potentially hazardous waste include those for which no sampling data exists.

Exhibit 12-12
Significance of Regulatory Compliance Costs for Management of
Phosphogypsum from Phosphoric Acid Production^(a)

Facility	Subtitle C			Subtitle C-Minus			Subtitle D-Plus		
	CC/VOS	CC/VA	IR/K	CC/VOS	CC/VA	IR/K	CC/VOS	CC/VA	IR/K
Agri Chem - Bartow, FL	5.0%	5.5%	93.8%	3.4%	3.8%	62.1%	3.4%	3.7%	66.2%
Agrico Chemical - Mulberry, FL	12.6%	13.9%	239.8%	6.2%	6.9%	120.6%	3.6%	4.0%	72.4%
Agrico Chemical - Uncle Sam, LA	18.2%	20.2%	348.6%	11.9%	13.2%	224.1%	11.3%	12.6%	229.8%
Central Phosphates - Plant City, FL	32.4%	36.0%	618.2%	5.3%	5.9%	103.3%	3.1%	3.5%	63.5%
Chevron - Rock Springs, WY	5.7%	6.3%	104.8%	0.7%	0.7%	5.0%	0.3%	0.3%	1.6%
Gardinier - Riverview, FL	28.8%	32.0%	548.1%	5.3%	5.9%	101.0%	3.1%	3.5%	61.9%
Mobil Mining - Pasadena, TX	21.3%	23.7%	403.2%	5.9%	6.5%	111.2%	3.4%	3.8%	65.3%
Nu-South Industries - Pascagoula, MS	37.9%	42.1%	718.5%	7.9%	8.8%	150.8%	4.5%	5.0%	87.5%
Nu-West - Soda Springs, ID	5.5%	6.1%	102.3%	3.7%	4.1%	67.0%	3.6%	4.0%	67.0%
Occidental Chemical - White Springs, FL	4.3%	4.8%	82.8%	2.9%	3.3%	55.7%	2.9%	3.2%	55.7%
Royster - Palmetto, FL	36.4%	40.5%	690.0%	7.6%	8.4%	143.9%	4.4%	4.8%	84.5%

CC/VOS = Compliance Costs as Percent of Sales

CC/VA = Compliance Costs as Percent of Value Added

IR/K = Annualized Capital Investment Requirements as Percent of Current Capital Outlays

(a) Values reported in this table are based upon EPA's compliance cost estimates. The Agency believes that these values are precise to two significant figures.

Facilities evaluated here as generating potentially hazardous waste include those for which no sampling data exists.